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SOCIETY OF BRITISH GAS INDUSTRIES

DESPITE shortages in the supply of raw materials, difficulties in transforming raw products into semi-manufactured goods, acute shortages of manpower, due in certain key industries to maldistribution, and in face of all the complications of restrictions and controls, the Society of British Gas Industries is able to record in its 42nd annual report (to which we referred in the "JOURNAL" of May 21) that during 1946 plant, equipment, and appliances which the Gas Industry and the consuming public looked to the Society's members to supply came forward in increasing volume. Demand, however, remains far in excess of supply, and the report urges that every effort should be made to enlarge the total labour force and to ensure that the needs of the key industries are met. Every effort should be made, it says, to increase incentive and perhaps particularly in removing taxation deterrents.

Since the period covered by the report, purchase tax, under the 1947 Budget, has been imposed at 66⅔% on all domestic fuel appliances, many of which were freed from tax under the autumn Budget of 1945. It may be hoped that this drastic imposition—conceived as it was, like the increased duty on tobacco, not so much with the object of raising revenue as for restricting consumption—will be only temporary, but while it lasts its reaction on the appliance market is considerable. As a restricting factor the tax is certainly proving an unqualified success, but it is hindering the Industry from fulfilling its promises of improved domestic heat services and causing embarrassment to manufacturers who have concentrated on the domestic appliance trade. The very uncertainty as to the length of its duration is deterring those who could afford the extra cost from buying and prompting them to adopt a "wait and see" attitude. Visions of greater home comfort have also to a large extent vanished—again we hope only temporarily—with the degeneration of the housing programme into a big scramble for anywhere to live, and the raising of the tax is keeping those who are fortunate enough to have homes from putting in appliances which might well result ultimately in greater, rather than less, fuel economy. As the report says, the whole machinery of economic control should be reviewed, and such controls as are still essential must be made to function smoothly and expeditiously. Now that the position of the country is officially admitted to be extremely serious means must be found of closing the gap between supply and demand in any and every way, except for the shortest possible period as an emergency measure, that of restricting demand and keeping down imports.

If an all-out nationalization policy is pursued by the Government, the Society's members will have to face profound effects from more than one direction—from a State-owned Gas Industry on the one hand and a nationalized iron and steel industry on the other. On both sides, however, they are in a fairly strong position, for the Society has consistently maintained the closest contact with the various Government Departments responsible for the exercise of control over the various branches of activity covered by the members, and the Council "believes that the work which the Society has sought in recent years to do as the medium of contact between the Government Departments and its members has had important results." An atmosphere of confidence in the organization has been created.

As buyers and sellers, the supply side of the Industry and the members of the S.B.G.I. are on opposite sides of the counter, but their common aim is to render service to the community, and the report bears witness to the spirit of co-operation in which that aim is being pursued. The Gas Research Board is the most notable example of that co-operation, sponsored as it was by the Institution of Gas Engineers and the S.B.G.I., and now that the war is over the Society's members are taking the full share which it was their intention from the first to take in its work. A joint consultative committee of the British Gas Council and the S.B.G.I. is doing harmonious and fruitful work on the domestic side and negotiations are in progress to explore the possibilities of a similar committee for the industrial field. It would be idle to claim that 100% of the manufacturers are members of the Society, for there are many firms supplying gas equipment whose major interests are in other directions, but it cannot be denied that its prestige has grown progressively through the 40 odd years of its history, and its members are in a strong position to meet the problems of the future. "Trading members" are increasingly welcomed into the District Associations and have recently been admitted to the London Juniors. Like the supply side, the trade needs new young blood, and the Institution's book on "Careers in the Gas Industry" does not omit to mention the opportunities which that sphere offers to the energetic and ambitious.

THE WALES MEETING

THE abnormally heavy burdens imposed on members in recent weeks by demands which have taxed the productive capacity of their works to the limit, by the fuel crisis and the weather, gave the annual meeting of the Wales and Monmouthshire Association of Gas Engineers and Managers at Cardiff a fortnight ago an air of austerity. Nevertheless, it was a good meeting in the technical and business sense and did credit to the President and especially to the Secretary, Mr. Darrell W. Rees, who was filling that office for the first time. The social duties, which had for so many years been carried out by Mr. Joe Sadler, whose death was mourned, also fell on Mr. Rees's shoulders, and no one could have done the job more successfully. Mr. Sadler was one of those "trading members" who are pre-

News in Brief

Eighteen Original £10 Shares in the Boston Gas Light and Coke Company offered by auction at Boston were withdrawn at £20 each.

The Registered Office of the Wharncliffe Silkstone Colliery Co., Ltd., has been changed from Tankersley, near Barnsley, to Keresforth House, Keresforth Hill Road, Barnsley.

Dundee Gas Committee is inviting applications for the post of Assistant Engineer, rendered vacant by the promotion of Mr. W. S. Johnston to be Engineer and Manager.

On June 25, at the Showrooms of the Colchester Gas Company, Mr. R. J. Gregg, of Ascot Gas Water Heaters, Ltd., will give an address n a series of House Craft Courses presented under the auspices of the Women's Gas Council. The title of the talk is "Bouquet for Housewives."

Chesterfield Gas Committee has accepted a tender for the construction of a new chimney and boiler settings for three Lancashire boilers, and ancillary works, required at the gas-works in connexion with the scheme, estimated to cost £130,000, for the provision of new carbonizing plant.

At the Annual Cookery Competition, held by the Alliance and Dublin Consumers Gas Company, the adjudicator had to rely on cookery essays as a sub-title for practical tests. Awards ranging from £1 to certificates were awarded to more than 600 pupils of technical, secondary and elementary schools, within the company's area. Mr. John McCann, a Director of the Company, conducted the distribution.

Scottish Manufacturers of domestic gas appliances report that the industry has recovered its position after a limited slackness due to the purchase tax. There is still criticism of the tax among managements, buyers, and consumers, directed mainly at the classification of cookers as luxury articles. Orders are maintained at a maximum level and showrooms are finding that the public will pay the amount asked for the new equipment without question.

Skegness Gas Committee is recommending a reduction in the price of gas as and from the quarter which commences in July. A block scale of charges will replace the old method and for the first 5,000 cu.ft. per qr. the new charge will be 5s. 9d. per 1,000 cu.ft. for ordinary meter and 6s. 3d. for slot meter, decreasing according to the amount consumed. The gas undertaking had a "windfall" last year in the shape of a surplus of £4,500, against an estimated surplus of £45 and output is climbing monthly.

The Publishers of "Field's Analysis" of the Accounts of the Principal Gas Undertakings in England, Scotland, and Ireland, to the new edition of which we made editorial reference on May 7, announce that owing to a printer's error the figures in the column headed "Allied Undertakings—Per Therm Sold," on page 2/13, are out of alignment. They have issued a correction slip to be gummed over the column affected.

Competition for the Coventry Sheet Metal Workers' Football Challenge Cup, suspended during the war years, has been revived. The trophy was originally a shield made and presented by Mr. G. Wilson, founder of George Wilson Gas Meters, Ltd., in 1908. This was replaced by a cup given by the late Mr. J. H. Wilson, Chairman and Managing Director, in 1935, the first winners of which were George Wilson Gas Meters, Ltd., who have won it on several occasions. This year's final will be played on June 12 between Coventry Radiator and Presswork Co. and George Wilson Gas Meters, and the proceeds of the match will be devoted to assisting the superannuated members of the Coventry Sheet Metal Workers.

Perth Town Council is experiencing difficulty in carrying into effect a proposal that it should take over Abernethy Gas-works. The proposal was first made over two years ago after Perth had been called in to deal with difficulties which had arisen at Abernethy works. Up till now the Ministry of Fuel and Power has refused to make a direction to the Town Council to take over. A suggestion by the Ministry that the Perth Town Council should run Abernethy Gas-works is not acceptable to the Council, as it would then be involved in administrative responsibilities. The Regional Gas Officer suggested that Abernethy Town Council might adopt the Burghs Gas Supply Act and then ask Perth Gas Department to manage the works on its behalf. This suggestion was discussed by the Town Clerks of Perth and Abernethy, and the latter pointed out that adoption of the Act involved a cumbrous and lengthy procedure. A sub-committee of Perth Town Council is still trying to find a solution.

Accrington District Gas and Water Board is hoping for a decline in the demand for gas as a result of the summer heating restrictions. Mr. A. Harrison reported to the Board last week that the gas supply for April showed an increase of 19.6% over last year, and was still increasing. It was expected heating restrictions would bring down the demand.

"Britain's Best" Exhibition

The promise of quick delivery of goods, which was the outstanding feature of the first "Britain's Best" Engineering and Metalcraft Exhibition, held last month at the Royal Horticultural Hall, Westminster, has resulted in foreign buyers placing substantial orders with many of the 60 firms exhibiting. Buyers from all parts of the world attended the exhibition. Firms showing such highly technical equipment as radar received enquiries from Sweden, Turkey, and South American countries; companies manufacturing factory plant, hardware, metal furniture, jigs and tools, and other engineering plant all report excellent business. Short and Harland, Ltd., manufacturers of a prefabricated beach hut, found that home and foreign buyers were purchasing the huts to use as houses, offices, week-end cottages, children's playrooms and sun parlours.

"The aim of the exhibition was to show that British engineering and metalcraft firms are able to produce good quality products at competitive prices," stated Mr. R. Derwent Savage, Managing Director of the "British Bulletin of Commerce," organizers of the exhibition. "I think we succeeded. Buyers from all parts of the world told me how impressed they were with the inventiveness, the ingenuity and the craftsmanship displayed by the firms in the exhibition."

One example of the enterprising way British firms are seeking world trade is that of an engineering firm—W. Whitfield, Ltd., of Stroud, Gloucester. This firm, established in 1772, offers to design and build plant to the customer's specification—in other words to *invent* engineering equipment to order. This enterprise attracted great attention of visitors to the exhibition and enquiries for many thousands of pounds worth of business were received.

The second "Britain's Best" Exhibition will be held in November this year.

Diary

June 9.—London and Counties Coke Association: Technical Committee, 2.30 p.m., Gas Industry House.

June 10.—National Federation of Gas Coke Associations: General Committee, Gas Industry House, 10 a.m.

June 10.—National Federation of Gas Coke Associations: National Technical Committee, 11.30 a.m., Gas Industry House.

June 10.—Solid Smokeless Fuels' Federation: Technical Committee, 2.45 p.m., Gas Industry House.

June 10.—British Gas Council: Central Board, 2.30 p.m., Gas Industry House.

June 10.—Manchester and District Junior Gas Association: Ladies' Day. Morning visit to the works of General Gas Appliances, Ltd., Audenshaw; afternoon visit to Buxton.

June 11.—Yorkshire Junior Gas Association: President's Day, York. Inspection of works, 11 a.m. Afternoon visit.

June 11.—Eastern Junior Gas Association: First Annual General Meeting, Peterborough Gas Company's Showrooms, 2.15 p.m.

June 11.—National Benzole Association: Annual General Meeting, Wellington House, Buckingham Gate, S.W.1, 3.45 p.m.

June 12.—Midland Counties Coke Association: Central Committee, 2.30 p.m., King Edward House, Birmingham.

June 12.—Lancashire and District Coke Association: Annual Meeting and Luncheon, Grand Hotel, Manchester.

June 13.—Federation of Gas Employers: Annual General Meeting of Members in Scotland. North British Station Hotel, Edinburgh, 2.30 p.m.

June 14.—London and Southern District Junior Gas Association: President's Day; Summer Visit to Portsmouth.

June 19.—Industrial Gas Development Committee, Gas Industry House, 2.30 p.m.

June 20.—Manchester District Association of Gas Engineers: President's Day; Visit to Blackpool.

June 23.—London and Counties Coke Association: Finance Committee, 11 a.m.; Executive Committee, 11.30 a.m.; Central Committee, 1.30 p.m.; Gas Industry House.

Illuminating Engineering Society

The first post-war annual dinner of the Illuminating Engineering Society was held at Grosvenor House on May 14 under the Presidency of Mr. J. S. Dow, and was attended by over 250 members and guests.

Lord MARLEY, Chairman of the Colour and Lighting in Industry Council, proposed the toast of the Society and said that in less than 40 years—it was founded in 1909—the Society had achieved national and international importance. Its 2,000 members were almost all either brilliant scientists or people with a brilliant scientific future. There had been no more exciting times in which to live than the days through which we were not passing, in that there was a greater opportunity than had ever existed for the younger members of the Society to become contributors to the national good. The Society was not merely scientific. It was cultural, and existed to spread knowledge of the means, utilization, and effects of lighting. Widespread misunderstanding of lighting still existed in this and other countries, and it was only 10 years since it was deemed necessary to impose minimum standards of lighting in factories, because in many of them it was almost impossible to see what was being done.

Lighting became of increased importance during the war, and because of the black-out it was necessary in 1941 to introduce factory lighting standard regulations. His own experience in the Ministry of Aircraft Production showed a lamentable lack of understanding of the standards of good lighting in many of the factories which he visited. The eye was a delicate instrument, and lighting was therefore an important factor in the health of the worker.

The Colour and Lighting in Industry Council, formed through the good offices of the Industrial Welfare Society and the British Colour Council, had secured the valuable support of the Illuminating Engineering Society through the membership of Dr. Nelson and Mr. H. C. Weston. The importance of colour and lighting had been underlined by the reports of the working parties of various industries, and he invited members to study more particularly the report of the Wool Working Party. The cost of installing improved lighting in a factory might well be outweighed by increased output.

He congratulated Mr. Dow on having been in the Society since its inception, and on never missing a Council meeting for 37 years. He was a member of many Government Committees, to which he gave freely of his experience and knowledge.

The PRESIDENT, responding to the toast, said he regarded light as an essential tool in industry, and without it every worker must suffer just as surely as if he were deprived of his other essential tools. By diminishing illumination they might make some economy but they would pay the price in discomfort and inconvenience, in lower efficiency and in danger to life. He sympathized with those in high places, faced with difficulties which changed almost from hour to hour, who must often follow courses which they would prefer not to follow, but he was concerned that they occasionally followed courses which science did not endorse and to which human sense did not conform, especially when they imagined that we could endure the severity of an English summer without artificial heat and without artificial light. It was strange that we should be in that position, when light was cheaper than ever before in history, and when we had available sources of light which could so compare with daylight as to be almost indistinguishable. We had good and bad artificial lighting, but it was surely illogical to assume as some people did that artificial light was something inferior and even dangerous.

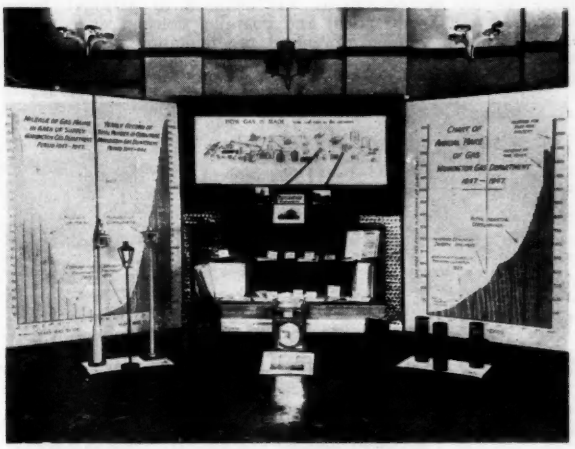
Hopes of better public lighting had been inspired by a report issued by the Ministry of Transport before the war. It therefore came as a damper to learn that the first public announcement made by the Ministry after taking over all public lighting was in the form of a suggestion that all lighting should be extinguished at midnight—a definite but not a satisfactory way of achieving uniformity of lighting. That was a passing phase and he hoped the time would come when the deprivation would be modified and they would be able to plan their lighting as they desired.

Mr. J. G. HOLMES proposed the toast of the guests, and referred especially to the presence of Mr. V. Z. Ferranti (President of the Institution of Electrical Engineers), Mr. V. W. Dale (Secretary of the British Electrical Development Association), Mr. W. J. Jones (Director of the Electric Lamp Manufacturers' Association), Mr. W. N. C. Clinch and Mr. H. O. Davies (President and Secretary of the Association of Public Lighting Engineers), Miss Caroline Haslett (Director of the Electrical Association for Women), Dr. N. A. Halbertsma (President of the International Commission on Illumination), Dr. J. W. T. Walsh, Sir Stewart Duke-Elder (President of the Faculty of Opthalmologists), and Mr. A. W. Oxbrow (President of the British Optical Association).

Dr. CHARLES HILL (Secretary of the British Medical Association) made the wittiest speech of the evening in responding on behalf of the guests. He remarked that the profession which he represented needed all the illumination possible to defend it against the forcible wooing of the Ministry of Health.

Warrington Centenary

In conjunction with the Warrington Centenary Industrial Exhibition, held to commemorate the incorporation of the Borough of Warrington, in 1847, the Corporation Gas Department staged displays in the windows of its main showroom in Buttermarket Street, Warrington.



In the glass case are included records of the actual proposal to supply gas lighting to Warrington, by Messrs. Barlow, of London, dated 1820. Records of the Warrington Gas Company from 1822 to 1877, when the undertaking was acquired by the Corporation, and the progress of the Department in the last 70 years, made up a most interesting exhibit.

Testing Vitreous Enamel Finishes

British Standards have just been published for defining acid-resistant and alkali-resistant enamels and for standard methods of testing vitreous enamel finishes. For some time it has been recognized in connexion with vitreous enamel finishes that in order to maintain quality and uniformity standard methods for assessing their value were essential. The need became imperative during the work of the Institution in connexion with the development of standards for domestic appliances and articles for the Ministry of Works building programme, and in 1944 a technical committee was formed to deal with the matter.

This committee, which has actively collaborated with the Institute of Vitreous Enamellers and with the Research Laboratory of the Gas, Light and Coke Company, restricted from the outset their investigations of methods of testing vitreous enamel articles for general purposes. Special vitreous enamel finishes for chemical or other industrial purposes for which special properties are required have been excluded.

All methods at present in use, both in purchasing specifications and in research laboratories, have been investigated, and after careful consideration it was decided to limit the recommendations to methods for the determination of the following which are incorporated in Part 1 of this Standard. (B.S. No. 1344, 1946). Acid resistance (qualitative and quantitative methods); alkali resistance; resistance to thermal shock; heat resistance of vitreous enamelled cast iron; and abrasion.

This standard does not include standards for vitreous enamel finishes, but prescribes standard tests for use in specifications for vitreous enamel articles. The tests cover the main properties of vitreous enamels and their suitability for practical use. It does not follow, however, that all vitreous enamelled articles will be called upon to withstand every working condition for which the tests have been devised. Discrimination must be exercised in specifying them in whole or in part, and it is suggested that in such specifications a selection should be made from the recommended tests and limiting figures agreed according to requirements.

In the absence of generally agreed methods for determining the performance of vitreous enamels industry when a good quality enamel was required, has generally called for acid-resistant and alkali-resistant enamels, and these terms have become established to describe and define high grade enamels for general purposes. The difficulty of specifying what is meant by "acid-resistant" and "alkali-resistant" have in the past led to confusion, and in the view of the committee the time has now arrived for the definition of these properties. Standards of acid-resistant and alkali-resistant vitreous enamels based on the standard tests are incorporated as Part 2 of this standard.

Edinburgh Demonstrations

The Edinburgh Gas Department has just held a series of very successful cookery demonstrations in its main showrooms in George Street. The demonstrations were conducted in co-operation with the Ministry of Food and were specifically designed to meet the needs of apartment and boarding house keepers. Publicity for the demonstrations was confined to personal letters addressed to 300 apartment and boarding house keepers in the City, of whom 200 acknowledged the invitation and expressed their intention of attending. The total attendance was 190 for the two sessions.

Boarding house cookery in a large scale oven.

The cookers used for the demonstrations were of the large scale type in order that the guests might see the type of equipment in which the specialists in their sphere do their work and that boarding house keepers who may have attempted to do a large scale job on ordinary domestic appliances might be introduced to the correct type of equipment for their purpose. The opportunity was also taken of advocating the installation of small boiling water appliances.

Time and Motion Study

The craft unions, whose membership includes over 300,000 of the most highly skilled operatives in a wide variety of industries, have defined their attitude to the time and motion study of industrial processes in a special report. The report suggests that full advantage should be taken of this technique in order to increase production and lessen fatigue, but proposes that it should be employed in consultation with the trade unions in order to avoid suspicions of exploitation.

The report states that motion and time studies comprise two distinct, though closely related functions. In theory, or in wartime urgency, it might be held that motion study had no connexion with time study; but under peace-time conditions, motion study often becomes the basis of time study and in these circumstances cannot be divorced from it.

War-time experience has indicated that motion study is more easily applicable to light industries, particularly where repetitive or mass production methods are employed. In other industries, particularly in the heavy industries, *e.g.*, mining, the work and the method of attack constantly varies, and does not, therefore, lend itself so easily to anything in the nature of motion study.

Time study is reputed to determine the period of time that an average worker should require to perform an operation, working at normal speed under set conditions; for the purpose of establishing such standard time as a basis for paying workers according to their output. It also assesses contingencies which occur during the performance of a job which should be paid for in addition to the rate allowed for the job itself.

The trade union view on this question of timing in connexion with wage fixing is that an agreed hourly or weekly wage should be guaranteed and piece-work prices fixed so as to enable a worker of average ability to earn a given percentage above the hourly or weekly day-time wage. This wage is a matter for negotiation with the employer by the trade union official acting on behalf of the worker.

The report adds that, generally speaking, workers seem to regard with suspicion any attempt to impose either motion or time studies, though in the case of motion study, when its introduction is made with the consultation and approval of the trade union representatives, the workers' fears of exploitation are removed; but there is a great volume of opinion against the practice of time study. Much of this is based on adverse practical experience which suggests that much of the time and cost of time study methods and personnel is wasteful and unnecessary. But there is a minority opinion which is less severe and this is entirely conditional upon joint consultations between management and workers' representatives. Where there is confidence in ability to solve industrial problems by the management, the workers and their trade union representatives, there are not many reasons for extraneous assistance from time study experts.

Where the application of scientific methods of production can be proved to be of advantage not only in the rebuilding of our export trade, but also to industry generally and to the workers employed, in the opinion of the Committee, they should be welcomed. So far as motion and time study schemes are concerned, if it is necessary to introduce them at all, it is of the utmost importance that the workers and their trade union representatives should be consulted at all stages.

An Up-to-Date Motorcycle Works

The various processes connected with the manufacture of modern motorcycles call for a fuel that is speedy and capable of exact control. At the extensive works of Associated Motorcycles, Ltd., Plumstead, London, town gas is used in all stages of the production of Matchless and A.J.S. machines.

The South Metropolitan Gas Company supplies Associated Motocycles with some 350,000 therms of gas each year and the firm not only uses it for all its motorcycle production requirements, but also for the air-conditioning of the works, the heating of offices, and throughout its extensive kitchens and canteens.

During the war over 80,000 motorcycles left the works on Government contracts, and to-day the entire plant is concentrated on the production of 350 c.c. and 500 c.c. machines for the home and export markets, on a fifty-fifty basis. Hundreds of lathes and presses in the extensive machine shops are devoted to the wide range of component parts going to the complete machine, and from here the production lines lead direct to the large heat treatment shop, where it is essential that such parts as bearings and axles are subjected to the most careful processing. Carburizing is carried out in six large furnaces. Two similar furnaces are used for refining, and the plant also includes three salt baths. Low-pressure gas is used throughout, and all annealing and case-hardening processes are controlled at maximum temperatures of 900° C., by means of Cambridge recorders and regulators.

The modern motorcycle is, of course, built up on a tubular steel frame and this, together with the large requirements for such components as tanks and exhaust pipes, places great emphasis on the importance of the brazing shops. This work is carried out by large coal gas/air blow pipes. A specially high standard of craftsmanship is vital for this operation as it is of supreme importance that perfect joints are made, and that the strength of the metal is in no way impaired by overheating. Naturally all work is subjected to a rigid system of inspection. All parts which must be enamelled are first treated by the "Bondor" rust-proofing process which consists of suspending components, contained in large metal charge-baskets, in chemical baths at a temperature of 180° F. These baths are of 700 gall. capacity and are heated by two L-shaped pipes passing through the tank, conveying hot gases from a large gas jet located at the lower end of each. Chemical action takes place between the solution in the tanks and the submerged components, resulting in the formation of an anti-rust surface. This special method of heating is adopted owing to sediment precipitation during the process. Direct flame contact would lead to early solidification.

Slow moving continuous conveyors take bondorized parts to the paint spraying department, prior to which they pass through a degreaser and a dryer. Enamel is applied either by dipping or spraying, and components then enter any of the battery of four 30 ft. continuous drying ovens of the open heater pattern. These ovens are maintained at a temperature of 440° F. by a stream of heated air entering through louvres along the sides.

A large number of non-enamelled parts find their way to the plating shop to be coated with nickel, chromium, or cadmium in the range of gas-heated plating vats.

The firm maintains a fully-equipped tool shop attached to which is an independent heat treatment shop for exclusive use in connexion with tool production. This is equipped with a high-speed tool furnace having a maximum working temperature of 1,400° C., a salt bath and tempering bath, operating at 900° C., and 600° C., and a muffle furnace.

Internal heating throughout the entire factory is by a system of air-conditioning, for which use is made of two thermostatically-controlled gas-fired boilers. These supply steam at 15 lb. pressure to a series of heating coils from which warm air is circulated as required. Heating of stores and offices is independent of the main factory system, and relies on circuits fed by four additional boilers.

Eastern Association of Gas Engineers and Managers

Annual General Meeting

VIEWS on the possible nationalization of the Gas Industry were expressed by speakers at the 111th General Meeting of the Eastern Association of Gas Engineers and Managers at Chelmsford on Thursday and Friday, May 22 and 23.

Proceedings on the first day began with the annual golf competition. Mr. T. C. Battersby, of Watford, was the winner of the challenge trophy presented by Mr. D. W. Turner for the member returning the lowest net score, and who had not previously held it. The George Wright Cup, open to members and associates, went to Mr. R. C. Wardell, of Boston; a silver salver was won by Mr. C. Byrt, Sheffield; a syphon holder by Mr. L. C. B. Williams, of Thetford; and two tankards by Mr. J. Hunter Rioch, Cambridge. A reception and dance at Cannon's Restaurant in the evening proved to be a particularly successful social function. The guests were received by the Mayor and Mayoress of Chelmsford (Alderman and Mrs. A. W. Andrews), and by the President of the Association (Mr. F. N. Howes, Chelmsford Borough Engineer and Manager), and Mrs. Howes. Many members of the Town Council also attended.

Business Meeting

There was an attendance of about 70 at the business meeting in the Council Chamber on the morning of the second day. The **President** was in the chair and expressed to members and their guests a cordial welcome to the County Town of Essex.

Mr. **H. H. Redwood,** Secretary and Treasurer, reported apologies for absence.

Sympathetic reference was made by the **President** to the death of "two of our good friends"—Mr. G. Swain, London, an associate since 1938, and Mr. A. J. Mumford, Secretary of the British Gaslight Company, a member since 1943. Members stood in silent tribute, and it was announced that letters of condolence would be sent to the relatives.

The resignation of Mr. H. Blakeley, of Leeds, an associate since 1929, was accepted with much regret on the motion of Mr. **J. Wright,** Bishop's Stortford, seconded by Mr. **R. Gavin,** Royston. Mr. Wright mentioned that Mr. Blakeley had spent a considerable portion of his life in the Gas Industry and did a great deal on its behalf.

Two new members, Mr. K. C. Rees, Watford, and Mr. B. C. Morton, Elland, were unanimously elected and warmly welcomed by the President.

Reporting on the work of the Council of the Institution of Gas Engineers, the **President** stated that the bulk of it had been associated with the preparation for a successful meeting at Birmingham. All outside contacts of the Institution had, however, been maintained, and the Institution was in fact doing a tremendous amount of work.

Education

Presenting the second post-war annual report of the work of the Education Committee, Mr. **F. Allen** (Clacton-on-Sea) said he was afraid he had to start with a grouse. In July, 1946, the Education Committee, he said, sent out 50 questionnaires as to the number of prospective students for the 1946-47 courses. Only 16 replies were received, and these covered only 13 professional students and 27 artisan students spread over the whole of the Eastern District. "We are unable to judge whether the lack of returns was due to lack of students or apathy on the part of senior executives," he went on, "but in either case we could not start localized classes with only these small number available and we have been powerless to do anything really constructive about classes for Manufacture and Supply students. This has caused the Eastern District students to sit for Institution Examinations as external students, but the entries for ordinary normal examinations are: 3 Diploma, 4 Higher, and 3 Ordinary Grade in Gas Engineering (Manufacture), 1 Higher, and 1 Ordinary in Gas Engineering (Supply). In addition, 27 Gas Fitting students have entered for the intermediate or final examination.

"In a general survey of the year's working I must make reference to the intensive courses in Manufacture and Supply for ex-Servicemen. Courses have operated or are operating at Bournemouth, Birmingham, Brighton, Bradford, and Westminster. Students have now completed the first of these courses and several students from the Eastern District have taken advantage of this method of overcoming the serious loss of training and opportunity caused by war service.

"The draft regulations for training and examination in Gas Salesmanship and Consumer Service have now been approved by the Institution of Gas Engineers and the British Gas Council, and it is hoped the schemes of training in Gas Salesmanship will be initiated in some Technical Colleges next September. It is, of course, general knowledge that it is proposed that the Institution of Gas Engineers' amended Education Scheme shall include a preliminary examination common to the Civil, Mechanical, and Electrical Institutions. This will spare students who are anxious to qualify for membership of more than one Institution a certain amount of duplication of effort. If these alterations in the examinations are approved as planned, the examination for Associate membership of the Institution is also likely to be amended to a slightly higher standard, between the present Higher and Diploma, to compare more closely with the Associate Membership examinations of the other Institutions."

He was pleased to record how heartily the Education Committee welcomed the formation of a Junior Association in the Eastern District and they looked forward to the duly accredited members of the organization joining the Education Committee during the ensuing year. He asked all senior executives to look through the 1945-46 report of the Gas Education Committee if they had not already done so. This was publication No. 302 of the Institution of Gas Engineers. He would prefer them to read all the report, but if they had only a little time to spare he asked them to read the Examiner's Report on the individual questions.

"It may be," he said, "that there is a serious lack of really up-to-date text-books in the Industry, or is it the students are being allowed no opportunity of thoroughly studying or even discussing plant of a type which does not happen to be fitted on the works on which they are engaged?"

In conclusion he referred to the indefatigable work of the Eastern District Education Committee's Hon. Secretary, Mr. R. C. Wardell, who had laboured manfully to help students throughout the area and had proved a tremendous asset to the furtherance of the work for education in their District.

Election of Officers

The ballot for the election of officers for the coming year resulted as follows: *President,* Mr. R. A. Weston, Norwich; *Vice-President,* Mr. C. E. Grimwood, Sudbury; *Council,* Mr. J. H. Greenacre, Great Yarmouth, and Mr. R. C. Wardell; *Secretary and Treasurer,* Mr. H. H. Redwood.

Upon the proposition of Mr. **C. R. Fowler,** Leiston, seconded by Mr. **C. B. Staniforth,** Ely, Mr. J. H. Troughton and Mr. H. R. Wimhurst were re-elected auditors with thanks for past services.

Practical Progress in Water Treatment

A Paper on "Practical Progress in Water Treatment" was then read by Mr. Philip Wedgwood, B.Sc., Watford and St. Albans Gas Company. The Paper was published in the "JOURNAL" last week, and a report of the discussion will appear later.

Question Time

A question left over from last year's meeting at Cambridge was answered by Mr. **R. M. Goodman,** of Retford. The question was: "What methods of coke preparation for the market are recommended for a works producing 1,000 tons of coke per annum? What would be the cost of grading of the recommended Institution Standards?"

Mr. Goodman prefaced his reply by quoting the following remarks made by Mr. W. L. Boon, late of the London Counties Coke Association, in his Paper to the Institution of Gas Engineers in 1941: "After the war, the consumer of fuel may be expected, not unreasonably, to raise a more critical voice on the fuels he uses, and it must also be anticipated that the competitive position between solid fuels will be more severe and enable him to exercise once more the freedom of choice between fuels which has not been possible during the war. Hence, coke quality will assume even greater importance in post-war fuel than perhaps it did immediately before the war."

Mr. Goodman said he believed Mr. Boon's forecast had been amply confirmed in the short period since the cessation of hostilities and that the necessity for the Industry to supply a standardized solid fuel of first-class quality would increase. This made it all the more important for the smaller Undertakings (selling approximately 1,000 tons of coke per annum) to make every endeavour to maintain and extend existing markets by keeping ahead on the technical as well as on the selling side. It was difficult to give an omnibus recommendation which would cover the many variables, such as type of coal carbonized, type of carbonizing plant used, and the nature of the coke market. But in general it was suggested that the recommendations of the Committee of Enquiry of the Institution of Gas Engineers should be followed with regard to standardization of sizes, and that in the majority of cases three sizes of saleable coke would be adequate. "Under-

takings," he said, "which carbonize in continuous verticals will almost invariably be able to produce three or even four grades by simple screening arrangements; where horizontal retorts or intermittent verticals are used, cutting will almost certainly be required to produce an adequate supply of No. 1 and No. 2 size coke, and while the initial demand may not justify this, provision should always be made in the scheme for the later installation of a cutter. With regard to the size of plant, it is suggested that a capacity of 5 to 7 tons per hour would be adequate to deal with almost all works and conditions of working.

"In giving details of designs of small plants, I feel it would be best to quote specific examples. I would mention, firstly, my suggestion for the small undertaking which has previously sold all coke either as run of retort coke or hand forked, and it is assumed that in this case labour exists in the yard for coke handling and loading. Such an instance could be met by the installation of a small reciprocating screen on short brick piers at a level at which coke can be shovelled on to it, and this is the cheapest and simplest proposition, which would probably cost, complete with foundations, brickwork, screening, and driving unit, about £500. The second case is the undertaking which has an existing and already partly developed market, and which could justify a slightly more expensive plant. A reciprocating, or multi-deck vibratory screen would be mounted on brick piers or steel structure at a height of about 6 to 10 ft., thus giving greater storage capacity on the ground for the graded coke. This particular problem must be considered according to the local conditions. With continuous verticals, it is probable that coke could be elevated in the retort house lift and the bogies run out to an overhead gantry and sent therefrom into a smaller hopper over the screen without cutting. In the case of horizontals, or intermittent vertical chamber ovens, a coke elevator would be necessary and the cutter could be installed either at ground level for hand feeding, or below ground with a receiving hopper to take the complete discharge from a coke barrow or skip. The cost of such an installation would depend very much on the local conditions and extent of the plant required, but should be between £1,500 and £1,800, depending on the height of screen, necessity for a cutter above or below ground, &c.

"There is one further example—namely, the portable type of plant. This could either be a simple hand-fed job consisting of a cutter with a debreezing screen below, or a more elaborate type comprising a small elevator, with or without cutter, and a single or double deck vibratory screen with deflecting and/or bagging chute. Such plants could be arranged for electric motor or petrol/paraffin engine drive. The cost of such plant ranges from £600 to £850.

"With regard to the cost per ton for grading, it is extremely difficult to give a figure and, quite frankly, there is a very great dearth of information on this subject which is entirely in the possession of members of the Industry. Costs are influenced by many factors, such as the capital cost of the plant, the amount of labour allocated to grading, the cost of motive power, the cost of wear and tear and maintenance. I believe, however, that a figure of about 3s. 6d. per ton of coke would cover the average cost for capital, maintenance and power, and I feel confident that this expenditure is more than repaid by the consolidation and improvement of sales."

President-Elect

Introducing the President-Elect (Mr. R. A. Weston, Norwich), the **President** spoke of his geniality and great sense of humour. At Norwich Mr. Weston had heavy responsibilities which he shouldered with great success. "During the war years he enabled us," he said, "to receive satisfactory supplies of coal when he performed the voluntary duty of Coal Supplies Officer with high efficiency. I cannot find in the history of this Association that Norwich had ever supplied a President, but I am glad this is now being remedied. I can hand over this office in sure confidence."

Mr. **Weston** agreed that Norwich had never supplied a President of the Eastern Association, but it did supply a President of the Institution in the late Mr. Thomas Glover. "I shall," he declared, "have a difficult task in following a very distinguished list of Presidents of which Mr. Howes is not the least. With good health and strength I shall endeavour to carry out the duties as well as I can. I have the authority of my Directors to invite you to Norwich next year." (Applause.)

Eastern Junior Gas Association

Report was made by Mr. **Hunter Rioch** that the Eastern Junior Gas Association was now an accomplished fact. The first annual meeting would be held at Peterborough on June 11. He felt this would be a red-letter day for the Eastern District, because for a number of years many of them had felt the need for this new association. It was one thing to have rendered some assistance in its formation, but it was another to see the members of the Junior Association received every possible facility. "It isn't always easy to allow them time to come to meetings," he said, "but I appeal to senior executives of gas undertakings to do the best they possibly can. If you are able to place a car at their disposal, please do so, for travelling facilities in this district are very difficult—and are even more difficult for so-called juniors. Give them all the assistance you can, including, if possible, their expenses."

Mr. **John E. Young** (Grantham) stated that a year ago a recommendation came from the Association to the effect that the Commercial Sections should be recommended to dissolve themselves. However, the Northern Section, comprising 25 members, had decided not to do so. He (Mr. Young) was Secretary and Mr. Reed the Chairman for the time being, and a meeting was held the previous week. In making recommendations for the betterment of the Commercial Section, they did not know where to submit them. "We are a child of this Association," he declared. "We discuss subjects that more properly come within the compass of the British Gas Council. We say we belong to the Association. We have not dissolved. What shall be do about it? We think the informal meetings of our Commercial Section have been very valuable. A lot of good work can still be done. We feel it should not be dissolved, but re-created within the compass of the British Gas Council."

Mr. **Reed** said they had their meetings at three-monthly intervals and although the attendances had not been large, he was bound to say the discussions and benefits they obtained had been of a high standard. "We are the child of this Association, but we deal with things that are outside the purview of this Association, matters which we feel come more correctly under the British Gas Council. The feeling of the meeting was that we would be perfectly happy to carry on for the time being until the British Gas Council sees fit to move.

Mr. **K. R. Mortimer** (March) said that as the Secretary of the almost defunct Southern Commercial Section of the Eastern Association he was in agreement with the views of Mr. Reed and Mr. Young.

Mr. **Bernard Clark** (Stamford) thought this type of work could come usefully under the ægis of the B.G.C.

Supporting the retention of the Commercial Sections, another speaker said he had found it of great help. He was one of the founders of the Southern Section.

Mr. **Hunter Rioch** said a year ago the Council gave serious consideration to this matter and unanimously recommended the disbanding of Commercial Sections. To-day a new and important point had been raised. It seemed to resolve itself into what he would call informal meetings. He doubted if work under the ægis of the B.G.C. was the right answer, and suggested the matter should be submitted to the Council for reconsideration—probably co-opting the chairmen and secretaries of the two Commercial Sections, and thrashing out the whole position.

The President: Does that meet with your approval?

The meeting approved the suggestion.

It was announced that the annual general meeting of the Gas Engineers' Guild will be held at Birmingham on June 4.

Luncheon

After the meeting the members and their ladies assembled at the Chase, Ingatestone, for a luncheon. There was an attendance of about 120.

The Loyal Toast having been duly honoured, Sir **George Evetts, O.B.E.,** submitted "The Corporation of Chelmsford." He said he thought the Borough of Chelmsford was very fortunate in its Gas Engineer. Chelmsford owned its own water as well as gas, and so far as housing was concerned it occupied seventh place in the country for the number of new houses completed. The town had developed considerably in recent years, and the gas undertaking had more than kept pace with that growth. The gas undertaking was purchased in 1918 and had proved to be "one of the bright spots" of the Corporation's activities. When taken over its debt was quite a big one, but since then the development had been such that the outstanding debt did not demand any great toll on the consumers of gas by way of interest and sinking fund charges. Chelmsford had several large industrial gas consumers, but no single one was so large as to over-balance the domestic load. He well remembered, while at the Air Ministry during the war, the generosity of the Corporation to erect a hydrogen plant. "We were very gratified with the outstanding success of the operation of the plant at Chelmsford," Sir George continued. "It was one of the most reliable and economic units we had."

On the question of nationalization, Sir George said it did not really matter who owned the piece of paper which represented the shareholding so long as the future owners left control of the Industry in the hands of the present people, who knew best how to run it. Provided political interference was not brought into the actual management and control, he did not think they need fear the future.

In reply, the **Mayor of Chelmsford** returned thanks for the compliments paid to the borough. Referring to Mr. Howes, he said that members of the Council fully realized the many difficulties Mr. Howes had had to face, especially during the war years, and appreciated the able way he shouldered the burden and maintained the high efficiency even when a great deal was being heard in the country about the difficulties of the Gas Industry during the fuel crisis.

Reply was also made by Mr. **G. E. Barford,** Town Clerk of Chelmsford.

"The Visitors and Press" was a toast given by Mr. **R. A. Weston,** and Mr. **F. Dawson** (President of the Southern Association of Gas Engineers) responded.

Giving the toast of "The President," Mr. **J. Hunter Rioch** described Mr. Howes as a very able and likeable man. Mr. Howes had a flair for getting over difficulties, and they had been impressed with his tremendous enthusiasm and with the ability he had shown in office. The great success of the conference reflected much credit on him and Mrs. Howes, and to them both went their very best wishes. Mr. Howes was a member of the Regional Gas Engineering Advisory Board for the Eastern Region and a member of its Executive Committee. No member of the Board rendered greater service. In addition, he was Chairman of the Eastern Section of the Domestic Gas Development Committee and they on the gas engineering side were conscious of the large amount of good work which the Committee is doing under his chairmanship."

The **President** acknowledged the toast.

Southern Association of Gas Engineers and Managers

THE Spring Meeting of the Southern Association of Gas Engineers and Managers was held at the Connaught Rooms, London, on May 20, under the Presidency of Mr. Frank Dawson, who announced that over 60 apologies for absence had been received.

Reporting the deaths during the past year of two members, the **President** said that it was with great sorrow that they had heard of the death of Mr. W. B. Leech, who had been station engineer at Beckton many years ago and was probably known to most of the older members, as well as that of Mr. T. Hardie, who was well known to all present. Mr. Hardie had been a great man in many respects—a great engineer and one who could be considered to have been a very bold and courageous man who had undertaken many activities during his years with the Gas Industry. Apart from being a great engineer, however, Mr. Hardie had been a very great man, unassuming in nature and character and although he had achieved a high place he had always been a great friend to the junior members of his staff. The name of Thomas Hardie, he was sure, would live long in the history of the Gas Industry.

Election of Officers

The **President** proposed the election of Mr. H. J. Escreet, the present Vice-President, as President for 1947-48. Mr. Escreet, he said, was well known to all present and his name was a household word in the Industry. He had always taken a great interest in the Industry and had been elected Chairman of the Eastern District for next year.

Mr. **J. H. Dyde,** seconding the motion, said he felt it was a fitting reward for the great work which Mr. Escreet had done, not merely for the Association but for the Industry in general, that he should be elected President. He had maintained close contact with the Gas Education Committee and his classic papers on distribution systems for the Institution of Gas Engineers also made him a very worthy man to take office, one who might well be described as the Walter Hole of our day.

Mr. **Escreet** thanked the meeting for his election.

Mr. **E. H. Cox,** proposing the election of Mr. L. P. Ingram as Senior Vice-President, said he had great confidence that Mr. Ingram, whom he hoped would rise to the office of President in the following year, would devote the whole of his energies to the post of Senior Vice-President and would carry out those duties to the entire satisfaction of all.

Mr. **W. K. Tate,** seconding the motion, said that Mr. Ingram had had a very hard time at Bognor and Chichester during the war. He would be sure to make an exceedingly good Vice-President.

Mr. **Ingram** said he was deeply conscious of the great honour which had been done to him. He had only been with them some three years in the south, following some 15 years in the "foreign parts" in the midlands, but he was a southerner, and his heart was in the south, and he could only hope to do his best by way of future efforts rather than past achievement to deserve the reward he had been given.

Mr. **T. C. Battersby** proposed, and Mr. **G. L. Braidwood** seconded, the election of Mr. J. H. Dyde as Junior Vice-President. Mr. **Dyde,** in reply, said he felt it was a great honour to serve the Association, and though he was a northerner and still followed the fortunes of the Yorkshire cricket teams, he was a southerner by adoption.

Mr. **S. L. Wright** proposed, and **Mr. E. G. Stewart** seconded, the appointment of Mr. C. F. Botley and Mr. J. H. Donaldson as Hon. Auditors. Mr. **F. Dawson** proposed, and Mr. **L. P. Ingram** seconded, the appointment of Mr. J. M. Webber as Hon. Secretary and Treasurer.

The meeting approved the Council's nominations for the Association's representatives on the Council of the Institution of Gas Engineers, and on the Benevolent Fund Committee of the Institution. The names of the personnel of the Eastern and Western District Committees and the new district representatives on the Council of the Association for the Eastern and Western Districts were read and accepted.

The election of new members was proposed by Mr. **P. E. Browne** and seconded by Mr. **E. G. Stewart,** and the new members were formally introduced to the meeting.

Gas Engineers' National Guild

The **President** explained that there had been received from the Secretary of the Gas Engineers' National Guild a request in accordance with the rules of that Guild for the appointment of two representatives from the Association on the Council of the Guild. The representation was to be on the basis of one member for each 150 members of the Association who were members of the Guild, and as it was understood there were 100 such members of the Association at present, the entitlement would therefore be for two members to be appointed. The Council, he explained, had given some consideration to this matter, and while it was admitted that there were some difficulties to meet, such as the question of whether the members of the Association ought to be members of the Guild—although it would appear to be desirable that they might—unfortunately at this particular meeting they were not acquainted with the actual members of the Guild present; and no call had been made for such a purpose. In those circumstances the Council had recommended that the two existing representatives sitting on the interim committee of the Guild should be asked to continue for a further period of twelve months, during which time it was possible that some of the problems in connexion with the selection might be sorted out. The two representatives in question were Mr. Ingram and the President himself, and they had intimated their willingness to continue.

In the absence of any other nominations, the motion was carried.

The **President** said a suggestion had been made by the Secretary as to the advisability of appointing a first reserve representative on the interim committee of the Guild owing to the fact that the two existing representatives might occasionally experience difficulty in being able to attend the interim committee meetings. In the absence of any nomination for this appointment, the resolution was abandoned.

The President then called upon Dr. F. R. Weston to read a Paper entitled "The Mechanism of Carbonization in Continuous Vertical Retorts—the Bow Common Experiment, 1945-1946." He said many members would recollect the Paper they had received from Dr. Haffner and Dr. Weston dealing with the first experiment which had been made in connexion with the quenching of vertical retorts. He felt it would be admitted that the first experiment was a trial, as a result of which a good deal had been learned of the actual technique, and in consequence it had been followed by what was known as the Bow Common Experiment.

The Paper will be published in a later issue of the "JOURNAL."

Cumberland & Westmorland Gas Managers' Association

The Spring Meeting of this Association was held at the Gas-works, Keswick, on May 15, under the presidency of Mr. J. George Pope, Engineer and Manager, Workington Gas Department.

The following were elected to office for the year 1947-48:

President, T. H. Large, Maryport.
Vice-President, T. B. Ashbridge, Silloth.
Secretary, W. B. Hetherington, Keswick.

Among those present was Mr. J. E. Blundell, a Past President of the Association, who until he retired from Carlisle took a deep interest in the affairs of the Association and gave much valuable encouragement to its formation.

The Autumn Meeting was fixed for Oct. 2, at Maryport.

A Symposium on Combustion

Gas Research Board Discussion

Following the annual business meeting of the Gas Research Board on April 16, an afternoon session was devoted to a discussion on "Combustion" introduced by Dr. D. T. A. Townend, Dr. Harold Hartley, Professor Sir Alfred C. G. Egerton, and Dr. R. F. Strickland-Constable.

DR. D. T. A. TOWNEND, Opening the discussion, said:—The terms of reference of a Symposium on Combustion are wide and I have been asked to deal particularly with academic advances in recent years. In the time available I will, therefore, endeavour to deal mainly with outstanding features and, in view of the objects of this meeting, to submit my remarks in most general terms.

Heats of Combustion

The attention of the Gas Industry should be directed to the work on heats of combustion forthcoming during the past decade from the American Bureau of Standards under Rossini. It is rather an amazing fact that little has been done in this field since the work of Julius Thomson some 60 years ago, and this is still that mostly presented in current books of reference; the determination of physical and chemical constants to-day provides little glamour to the free-lance scientist, and one, therefore, has to rely on State establishments. The motive for the American work has been the need for such constants in respect of higher hydrocarbons for the calculation of thermo-chemical data relative to catalytic synthesis in the petroleum industry. Much of the data, therefore, has little immediate significance to the Gas Industry, but the field has been treated broadly, and values in respect of the elementary combustible gases present in town gas have been either critically examined or re-determined.

Slow Combustion

It is in the field of slow combustion that the greatest advances have been made in our knowledge of combustion, and while at first sight they may not greatly affect the Gas Industry in so far as it is interested in energy release from combustible gases, their wider importance cannot be under-rated. Slow combustion between oxygen and a combustible gas takes place at temperatures and pressures well beneath those required for spontaneous ignition and the appearance of flame. Until about 1925 the thermal view held the field, according to which the rate of reaction depended upon temperature alone; when this was raised, the rate increased until a point was reached when the rate of heat release in the system exceeded that of its dissipation, the reaction becoming autogenous with the initiation of flame. A number of observations, many of which came to light about that time, led to the overthrow of this simple view and its replacement by the theory of "Chain Reactions." Typical observations were (a) the dominating part played by materials in small concentration, *i.e.*, inhibitors and promoters, (b) the occurrence of long induction periods, sometimes hours, before reaction sets in and spontaneous ignition ensured, (c) the part played in inert gases in not retarding reaction but actually accelerating it, and (d) the fact that reaction was critical to quite minor changes in pressure or temperature. The "chain" view explains that reaction is not dependent alone upon temperature rise but upon the fact that the energy released is confined to specific molecules or molecular fragments, maybe atoms or radicles, and that it is passed on from molecule (fragment) to molecule, the over-all reaction rate being determined by branching (multiplying) and breaking (destructive) processes. At first, the reactants were thought to be energized molecules, but Haber's work on flame spectra and the subsequent discovery that reaction could be induced by transference in the gaseous medium of suitable short wave radiation, led to recognition of the importance of such species as OH, HCO, O and H atoms. The presence of similar such species in flames is now recognised as responsible for their colour, for instance, CH provides the violet, and C_2 the green tinges in town gas flames. While spectroscopy has been a useful tool in revealing these species, it is by no means self-sufficient as they are unable to emit unless sufficiently energized, and flame temperatures are frequently too low to allow of this.

While this knowledge of the mechanism of slow combustion does not appear predominantly vital to the Gas Industry, from the point of view of energy release, its wider implications are important, particularly in the presence of atoms, &c., in flames. Fortunately, the behaviour in slow combustion of the comparatively simple constituents of town gas, kinetically involved though it be, provides few difficulties in practice, but with higher hydrocarbons the story is less simple on account of the formation of peroxide bodies which, *inter alia*, lead to the phenomenon of "knock" in internal combustion engines. The peroxide mechanism may have some importance (a) when the hydrocarbon constituents of town gas exceed more than a few per cent., (b) when gas-oil mixtures are used in compression ignition engines, &c., and possibily (c) with catalytic ignition devices.

Flames

There are two types of flames, explosion and diffusion flames, as typified by the dual character of the Bunsen flame; the inner cone is an explosion flame, the rate of flame travel being compensated by the feed velocity, thus rendering it apparently stationary, the outer cone being a diffusion flame where combustion depends, inter alia, upon the relative diffusion rates outwards of the combustible constituents, and inwards of the oxygen of the atmosphere. While the mechanism of combustion in flames is undoubtedly of a "chain" character, few phenomena are apparent which cannot well be interpreted on the elementary Le Chatelier thermal view, *i.e.*, that the heat liberated in the flame is adequate to raise the unburnt medium ahead of it to the ignition point; the logical interpretation is that the reactant centres necessary at the temperatures experienced are as easily produced by the average kinetic energy of the heated molecules as a whole, as by specific collisions. In the main, therefore, flame speeds of the separate inflammable constituents are characteristic, depending upon heat of combustion, oxygen requirement, conductivity, heat capacity, thermal losses, &c. And while we know that "chain" processes are involved, except in the combustion of carbon monoxide which is critical to the concentration of water and other promoters or inhibitors, there is little outward manifestation of them; indeed, rarely do inhibitors and promoters, &c., affect flame velocity to any marked degree.

This said, we have quite passed the period of speculation and know that atoms may be present in flames in concentrations exceeding that which can be predicted by known chemical equilibria involving atoms, e.g., $H_2O \rightleftarrows OH + H, CO + OH \rightleftarrows CO_2 + H_2$, &c.

Indeed, there have been in recent years two outstanding examples of experimental evidence for the presence of such atoms:—

(1) The second Arthur Duckham Fellow, E. C. W. Smith, demonstrated a year or two ago that the beautifully coloured luminescent effects produced by contact of the flames of hydrogen-containing gases with calcium oxide surfaces promoted by the oxides of certain metals, *e.g.*, antimony, pink; magnesium, golden yellow; tin and lead, blue; and bismuth, violet, were the outcome of the energy liberated from the recombination of hydrogen atoms on the surfaces referred to.

(2) Within the British Coal Utilization Research Association Dooley and Whittingham have demonstrated that the sulphates and sulphuric acid responsible for deposits and corrosion in water tube boilers, are the outcome of the combination of oxygen atoms and SO_3 liberated from the fuel bed reactions; and it has now been demonstrated that these oxygen atoms arise mainly from the combustion of carbon monoxide. It may well be, also, that the formation of nitric oxide in CO flames is conditioned by the formation of oxygen atoms, and such atoms are also postulated as the initial reactants in the combustion of hydrogen sulphide.

It is clear, therefore, that discussions involving atoms and free radicles in flame reactions are not mere highbrow moonshine, but have obvious practical significance.

Another factor which may be of importance in towns gas flames is the relatively greater diffusion rate of hydrogen than that of other inflammable constituents; for example, it may well transpire that the petal-like structure of inner cones of Bunsen flames burning hydrocarbons is due to two separate processes: (a) the combustion of hydrogen and (b) an initial cracking reaction giving rise to it. And this calls to mind the observation first made by Coward and Brinsley in 1914, and that although hydrogen and carbon monoxide do not differ greatly in heat of combustion, yet the lower limit of inflammability of hydrogen is 4.1%, and that of carbon monoxide upwards of 10%. What appears to happen in the low limit hydrogen mixtures is that hydrogen diffuses into the vortex ring type flame, thereby increasing the actual local concentration in it.

Burner Stability

The many factors concerned in the stability of burner flame are now much better understood. Two of apparent outstanding importance are: (a) combustion mechanism and flame speed, and (b) aerodynamic phenomena. There are aerated and non-aerated flames, the problem of light-back pertaining to the former and that of blow-off mainly to the latter. Recent researches have revealed that in light-back, the dead space between the base of the inner cone and the burner port, due to the thermal gradient between the cold uncombined mixture and the flame, exerts a controlling influence and is closely linked with the variability of the limiting small diameters necessary completely to eliminate the defect with varying supplies. And research in this field has also established the burner method as that most likely to furnish ignition velocities (flame speeds) as physical constants. Blow-off is associated with aerodynamical processes, the important factors being, at low velocities, an ignition ring external to the burner port and, at higher velocities, after the flame has actually left it, vortex formation.

It may become important in practice to secure a higher rate of heat release than is possible from normal flame combustion processes. This requires a more comprehensive study of the influence of physical disturbances; it is known that flame combustion in certain enclosures gives rise to the setting up of compression waves greatly accelerating completion of energy release. Alternatively, it might be possible deliberately to impose such waves. There also seems scope for the imposition of radiation from external sources on the combining gases. This may call for the development of super-refractories as will, indeed, the further development of Bone's incandescent surface combustion, or the use of permeable furnace linings.

The Burning of Solids

Great progress has recently been made in our knowledge of the burning of carbonaceous materials. At low temperature it is now known that the weathering and slow combustion of coal or carbon depends upon the formation of an adsorbed carbon-oxygen-water complex behaving as a hydro-peroxide. The decomposition of this complex gives rise to the overall oxidation of the lost material, and at 80° C.—the temperature known to be critical in the storage of coal—this decomposition accelerates rapidly. The general observation throws particular light on the combustion of carbon. As was demonstrated in the 80's, whereas rigidly dried carbon burns very slowly, even when raised to incandescence giving rise to carbon monoxide as the main product, moist carbon oxidises rapidly at much lower temperatures, giving rise to a mixture of CO_2 and CO, in which CO_2 predominates.

Reverting to combustion in fuel beds, an important advance has been achieved recently by the British Coal Utilization Research Association in the down jet method of combustion. Whereas it is necessary in normal fuel bed reactions to provide primary and secondary air for reasons well known, the down jet method enables complete combustion depends upon the availability of oxygen in step. This has been rendered possible by the knowledge that the initial product of combustion is carbon monoxide, and that its complete combustion depends upon the availability of oxygen in the voids and a suitable shallow bed. These factors may be controlled by the angle of incidence and velocity of the blast in relation to the fuel bed concerned. And lastly, the knowledge that the primary oxidation product is carbon dioxide has drawn attention to the important part which may be played by chance materials on the rate of its complete combustion, and therefore indirectly on the reactivity of the fuel concerned.

Domestic Utilization

Dr. **Harold Hartley**: In preparing the short Paper for this meeting I have limited myself to the consideration of problems which arise in utilizing town gas for domestic purposes. The subject has been divided into four sections dealing respectively with: (1) Ignition; (2) rate of generation of heat; (3) methods of utilization; (4) thermodynamic and aerodynamic aspects of the problem.

In the first section reference is made to a number of means which are, or can be, employed for igniting coal gas in air, and the question is asked, what are the common factors in these various methods? It is conceivable that if the coal gas/air mixture is ignited by an electric spark on the one hand, or by a heated platinum wire on the other, that although it is necessary to supply a minimum of energy in each case, that minimum of energy may be different for the different methods and may result in the production of the resultant products, carbon dioxide, steam, &c., from the reactants by different paths. It is suggested that perhaps the most satisfactory method of igniting coal gas may be based on the use of a gas flame. Nevertheless, there are objections to the maintaining of a constantly burning flame, and in practice endeavours have been made to adapt other systems. Experience with several systems suggests that none has yet been made perfect and yet the cause of failure is not always apparent. The unexplained cases have been suggested as arising from "the total depravity of inanimate things." Questions are asked as to whether variations in the composition of town gas have a major influence on the working of the ignition system and also whether the spectroscopist can suggest which is likely to be the most profitable line of attack.

It is plain that the advantages of coal gas arises from the fact that the flame is "infinitely adjustable." This language of advertisement is only correct, however, in a downward direction and it is felt that advantage would result if we were able to effect more rapid production of heat than is commercially practicable to-day. Attention is drawn to some of the data available concerning the rate of generation of energy by a variety of methods, and it would seem on the basis of published information that with coal gas flames this may vary between 1,000,000 and 40-50,000,000 B.Th.U/cu.ft./hr.

Mention is also made of the fact that in the case of some of the hydrogen/air mixtures, the speed of uniform flame movement is increased some 400 times when detonation takes place, and it is asked whether the phenomena of detonation and especially of its initiation can be explained in such a way as to permit of further consideration of the possibility of effecting such accelerated combustion in a controllable manner under ordinary atmospheric conditions.

Pre-Flame Combustion

Then again we have the heterogeneous combustion in contact with solids. Some 35 years ago Bone was led to suggest technical applications of the phenomena because he believed that under conditions of incandescent surface combustion, energy was generated more rapidly than in the homogeneous phase of freely burning flames. It is established that pre-flame combustion is much accelerated by the use of certain solid catalysts but we do not seem to have information as to whether a similar effect is continued above the ignition point. Then again it would be interesting to know whether the presence of an incandescent solid changes the reaction proper and whether incandescent surface combustion is actually flameless.

The so-called luminous coal gas flame has a number of attractive features from the standpoint of the appliance designer. The use of the calorimeter shows that the gross heat evolution is not influenced by the type of burner used, so that the end points reached in combustion are probably the same. It would be useful to have more information about the relative rates of heat production for the two types of burner. One question that is asked in the paper is for an explanation of the fact that if the Bray jet burner in the luminous flame gas fire is replaced by a Bunsen burner giving well aerated flames, the maximum brilliance of the fire is decreased, even though the Bray flames may have little intrinsic luminosity and the measured emission of radiant heat is unaffected.

Relatively little is known about the effect of gas composition on luminous flame characteristics. Larger amounts of oil are being used in the manufacture of town gas, and the increased hydrocarbon content of the resulting products has emphasized the limitations of our understandings of this mode of effecting combustion.

Under "Methods of Utilization" reference is made first of all to the effect of pollution of the atmosphere on the CO/CO_2 ratio for the products of combustion of freely burning flame. Attention is drawn to some results obtained by Hamilton Davies 20 years ago which show that the CO/CO_2 ratio is lower for the luminous flame than for the Bunsen flame, while on the other hand, results obtained by D. A. Winter in 1935 indicate that the luminous flame is somewhat more susceptible to the effects of the products of combustion at high concentrations than is the Bunsen flame. As there is an increased tendency to burn town gas fluelessly in the heating of living rooms, more information is required regarding the combustion results. Results have been summarized showing the effect of atmospheric pollution on the hygienic standard attainable with a Columnar radiant appliance. These clearly point to the undesirability of using flueless appliances designed to give a high radiant efficiency. It is essential that flueless apparatus should have ample supplies of air to the combustion zone.

The corrosion of materials is influenced by the sulphur content of the products of combustion. It seems to be greater the higher the SO_3 content. As it is possible to vary the SO_2/SO_3 ratio, it would be useful to have information to indicate how this can be increased.

Emission of Radiant Energy

From my point of view, the most interesting portion of the communication is the short section dealing with the emission of radiant energy directly by burning gases. The question is asked why more heat is not radiated directly by flames. To what extent this is consequent upon dilution by the surrounding air and also whether anything can be done to increase the proportion of heat radiated directly by coal gas flames. The work

of David, Egerton, Gaydon, Garner and others in this field is particularly interesting. The results obtained by the spectroscopist do not appear yet to have been fitted in to the theory of the mechanism of combustion. Garner showed what a marked effect traces of hydrogen have on the radiant heat emission from CO flames. It now seems to be accepted that the infra-red emission from CO/oxygen flames is largely chemiluminescent and emanates from the vibrationally activated CO_2 molecules, whilst the radiation from hydrogen flames is of thermal origin. The radiation from coal gas flames is principally due to excited CO_2 molecules and may well be much influenced by the composition of the gas and be susceptible to variation and control.

The concluding section of the Paper touches on the thermodynamic and aerodynamic aspects of the problems which confront the appliance designer. It is suggested that advantage may result from greater consideration of the problems from this point of view. The detailed application of such considerations to flames may throw light on the sequence of energy changes and the availability of energy at different stages in the process. Also, consideration should be given to the aerodynamic problems connected with the most effective utilization of the pressure energy available in the fuel and the air supplied to the flames.

One general result limitation in applying the results of academic researches is that the latter have been concerned largely with pure substances and simple mixtures, whereas the applied worker has to deal with more complex and varying mixtures in gases, liquids and solid fuels. There seem to be no general answers to the questions as to whether the fundamental characteristics of gas mixtures are reasonably simple functions of the corresponding characteristics of their components. It is known that for most of the mixtures of gases with which we are concerned, such characteristics as ignition, flame speed, limits of inflammability, emission of radiation, and so on, are not additive, at least in the terms in which we assess them. From the point of view of industrial application, is there any ideal town gas or is the gas manufacturer's horizon to be defined solely by economic considerations?

Industrial Application

In reviewing the progress in the last half century in the design of appliances for heat generation as distinct from power generation, it is difficult to avoid a feeling that such advance as has been effected would not have been delayed seriously had the academic work on combustion which has been carried out during that time been left undone. This seems totally different from the industrial progress in the electrical industry, whilst recent developments in the field of nuclear physics provide an even more striking contrast. In view of the importance to our civilization of heat generation by combustion, it is desirable that consideration be given to the question why there has not been greater advance. Is this due to a lack of useful background knowledge or to failure on the part of technicians to inform themselves about or appreciate the significance of known facts? Is it that combustion research has lagged behind because the end to be attained is not appreciated by the academic worker? If the work were co-ordinated with industrial needs, would this expedite progress? Is it that the university worker is too far removed from the realities of industrial life for more rapid progress, whilst the applied worker is too much engaged in the struggle for existence to be able to do a great deal to help along with "pure" research? There is need for closer contact between the workers in the university and the scientists engaged in industry. It is on the latter that progress in the immediate future depends, but they need the help and stimulation of the researcher into fundamentals. Is it not then to the Research Associations that we must look for an appreciation of the value of the results obtained by the fundamental worker and especially of their significance to the technician?

The **Chairman** (Dr. E. V. Evans):—I think we are faced with the fact that the long term problems must be the business of a Gas Research Board that belongs to the Industry, and the *ad hoc* problems should be dealt with in the laboratories of the undertakings and appliance manufacturers. Even if Dr. Hartley had stopped at his remarks this morning we should have had something to discuss in the Council, but after his contribution this afternoon there is a great deal to discuss arising out of his remarks. Our next speaker was to have been Professor Sir Alfred Egerton, but unfortunately he is in Switzerland with a broken leg, but we have Professor Newitt here to speak on his behalf.

Professor Sir **Alfred Egerton,** in the course of his communication, presented in his absence by Professor D. M. Newitt, pointed out that in recent years the understanding of combustion has been mainly related to slow combustion and ignition, as illustrated by the study of the hydrogen-oxygen reaction. A general similarity of behaviour is apparent, and the underlying mechanics of many combustibles is similar and can be considered as essentially peroxidation, although a peroxide may not actually be formed. In the phenomena of knock, however, the formation of peroxides is essential. Flame combustion is not associated closely with ignition phenomena (as shown by recent work on propagation in limit mixtures and the effect of "promoters"), but is dependent on initiation by radicals already present in the flame. Spectroscopic investigations, it is hoped, will yield more information on the mechanism of flame reactions. It has also been possible to investigate the mechanism in low-pressure explosions by freezing out products, the process being shown to be potentially a peroxidation. Further studies of vibratory flames and detonations are needed.

Dr. **R. F. Strickland-Constable**:—The purpose of my contribution is to make a brief review of the field of combustion research as a whole. The subject matter is divided under the headings of Chemical Theory, Physical Theory and the Study of Special Combustion Problems.

Chemical Theory

Investigation of the chemistry of combustion processes begins with the investigation of the combustion of the separate pure gases, such as hydrogen, carbon monoxide, methane and the higher hydrocarbons. Generally it may be said that the most important event in the recent history of this subject has been the discovery of chain reactions, and it now appears probable that most of the important reactions occurring in flames are of this type.

But before discussing chain reaction in general, reference must first be made to the subject of the slow combustion of hydrocarbons. When hydrocarbons are heated with oxygen at temperatures below that at which explosive reaction occurs they react slowly. Much work has been done in identifying the various intermediate chemical compounds that are formed in the progressive oxidation of the hydrocarbon to carbon dioxide and water. The reactions have been studied under a great variety of conditions, including high pressures, and a great deal is now known of the sequence of intermediate compounds that are formed. Unfortunately, identification of the separate chemical intermediate compounds of the slow low temperature oxidation reaction is only the first step in the elucidation of the mechanisms for the reactions by which the separate steps are accomplished are found largely to be chain reactions, and the unravelling of the chain mechanism presents further problems of great complexity.

The combustion of hydrogen and of CO are also both found to be chain reactions. The combustion of hydrogen is among the most thoroughly investigated reactions in the whole of chemistry; nevertheless, with all the work that has been done on it, it must be admitted that the particular chain mechanisms involved are still to a considerable extent matters for dispute. This applies even more to the oxidation of CO on which less work has been done, and still more to the mechanism of the hydrocarbon oxidation reactions which are, by the nature of things, more complicated owing to the considerable number of steps by which the final result is achieved.

Chain Reactions

In elucidating the mechanism of chain reactions, one of the principal methods of research has been the study of the kinetics. B, varying the conditions of temperature, pressure, surface, concentrations, &c., and observing the resulting reaction rates, it has been possible in a great many cases to build up elaborate reaction schemes postulating the existence of a whole series of atomic fragments to act as chain carriers. Outside supporting evidence for the existence of these atomic fragments is often lacking. And it now seems likely that in a number of reactions, kinetic measurements have been carried to such a point that more progress can be expected in this direction.

It must also be emphasized that chain reactions can only be studied by the usual kinetic procedure in the non-explosive region, and the nature of the explosive reaction can then only be obtained by deduction from the mechanism of the non-explosive chains. Furthermore, the reactions in flames are taking place at 1,200° C., and over, whereas nearly all our knowledge of the kinetics is based on measurements made at under 600° C. Our information on the mechanism of flame reactions is seen, therefore, to be very indirect.

Further progress in the study of flame reactions would appear to demand some more direct evidence as to the nature and concentrations of the chain carriers which are actually present in flames. New direct evidence about such transient atomic fragments with life times of the order of a millionth of a second or less, is obviously difficult to obtain. However, one of the most hopeful lines would appear to lie in the field of spectroscopy.

The emission spectra of flames both in the infra-red and in the visible and ultra-violet, have already been considerably investigated. The principal emission of radiation from aerated flames in the visible and ultra-violet regions, is due to the electronic transitions of precisely those types of atomic fragments which may be acting as chain carriers in the combustion reactions. The conclusions which can be drawn are, however, subject to the limitation, that only those radicles will disclose their presence that are chemi-luminiscent—that is to say, which are produced in

an electronically excited state by the combustion reactions, and in this way therefore we can only gain information about comparatively few of the chain carrying particles.

Flame Spectra

Hitherto, as Gaydon has pointed out, the observations that have been made on flame spectra are largely qualitative, and as a result little knowledge has been gained concerning the concentration of the emitters. Much further work is needed to gain as much quantitative information as possible by spectroscopic means.

It would, however, also be desirable to have some means of studying the non-luminescent chain carriers. Gaydon has pointed out that, provided sufficient dispersion is used, the ultra-violet electronic spectra may sometimes be observed in absorption. In the case of absorption spectra, chemi-luminescence of the observed particles is not necessary and this method might therefore provide a means of investigating those chain carriers which are not obliging enough to be chemi-luminescent. It is therefore suggested that the possibilities of this field of investigation are worthy of particular attention. The method could be applied, not only to oxidation reactions, but also to any explosive chain reaction.

It is also pertinent to enquire whether there is not a possibility of identifying the vibration spectra of diatomic chain carrying particles in the infra-red. They undoubtedly must emit vibrational radiation, although the practical difficulties of observing it may be too great.

Apart from the spectroscopic, one other method suggests itself for the investigation of the concentration of one particular atomic fragment. E. C. W. Smith has studied the subject of candoluminescence. If lime containing certain small quantities of other oxides is heated in a flame it gives off light, and Smith has shown that this is most probably due to atomic hydrogen. This phenomenon might therefore provide a means of determining the concentration of hydrogen atoms in flames by calibrating the candoluminescence surface in a known concentration of hydrogen atoms.

Effect of Flame Velocity

Another general method which might contribute to a knowledge about flame reactions may be found in the study of the effect on flame velocity of the addition to the flames of small quantities of foreign gases chosen as being specially capable of producing chain carriers. Although it is not possible to measure directly the speed of an explosive reaction, nevertheless the velocity of flame propagation must be a function of reaction velocity, and flame velocity measurements would provide, at any rate, qualitative information on reaction velocity. Useful information might therefore be gained by a systematic study of the effect on flame velocity of the addition of small quantities of substances which are known from other sources to provide chain carrying radicles, or alternatively, are known to be capable of breaking particular chains. Work of this nature has certainly been done in the past, but not, it is believed, in any very systematic manner with this particular end in view.

Returning to the subject of the slow oxidation of hydrocarbons, a possibly useful method of following these reactions suggests itself in the new form of the automatic gas analysis system which has been developed in Germany and recently disclosed in this country. In this method it is possible to get almost continuous readings of the concentration of any one constituent of a gaseous mixture. (Very briefly, it may be explained that light with a continuous spectrum is passed through a cell containing the gas mixture which is to be analysed. This cell may be termed the absorption vessel. The light, after passing through the absorption vessel, goes to another vessel—the analyser—containing a pure sample of the particular constituent gas which it is desired to determine; let us say it is CO. The CO will absorb radiation only in the CO absorption bands. The rate of heating of the CO in the analyser will therefore depend on the amount of this light which has *not* been absorbed by the CO in the absorption vessel. The concentration of CO in the absorption vessel is therefore measured by the rate of pressure rise in the analyser. By an ingenious system of intermittent illumination, readings of the rate of pressure rise are recorded every sixth of a second). Actually the apparatus records the concentration of any particular constituent at intervals of one-sixth of a second.

Although expensive, this apparatus appears to promise considerable advantages for kinetic work and its use for this purpose is well worth investigating. A possible limitation occurs in the case of gases with overlapping absorption bands. Its use in the case of the slow combustion type of experiments appears to be specially indicated.

The apparatus achieves, of course, no more than could be done by continuous recording of the strength of an absorption line observed in a spectroscope, but it would appear to have considerable advantages in simplicity and convenience of manipulation over the latter method.

Heterogeneous Combustion

Mention must also be made of the subject of heterogeneous combustion. The effect of surfaces on combustion is perhaps of special interest to the Gas Industry. Surfaces can act in two ways which must be clearly distinguished. They can either catalyse gaseous reactions in the classical manner, or they can initiate and break chains in the homogeneous phase. In the case of catalysis the chemical action takes place on the surface itself, and any active particles formed remain on the surface and only return to the gas phase after recombination to stable molecules. In the case of chain reactions, the active particles are first formed on the wall surface but are then reinjected as such into the gas phase, where they affect the rate of the homogeneous reaction. No special name has been accorded to this important class of action, and it is suggested that catanesis might prove suitable.

It should be quite easy to study the catalysis of gas reactions at flame temperature by working with electrically heated catalyst surfaces in very low pressures of gas, in vessels whose walls are at room temperature. The gas being at very low pressure and cold, chain reactions would be effectively suppressed and all that would be measured would be the catalytic reaction on the heated surface. Thus, the catalysis of gas reactions by refractory and other surfaces could be conveniently studied.

To investigate the effect of surfaces for catalesis, *i.e.*, for chain initiation at flame temperatures, is much more difficult. The most hopeful approach is to study the effect of surfaces on the chain reactions below the temperatures at which they become explosive. This has, of course, been done to a considerable extent when studying the kinetics of the chain reactions, but more from the point of view of throwing light on the chain reactions than from any special interest in the surfaces themselves. A special study of the effect of surfaces *qua* surfaces, on chain reactions might therefore be worth while.

Physical Theory

Many branches of physics are of importance in studying combustion problems.

(1) *Diffusion and Thermal Conduction in Gases.* Knowledge of the rates of pure thermal conduction and of diffusion in gases are frequently required, particularly in problems concerning the rate of propagation of flame. Diffusion coefficients are also specially necessary in discussing diffusion flames. It appears that few measurements of thermal conduction or of diffusion rates have ever been made at temperatures much above room temperature. Nearly all the available figures that are used are derived from calculations based on kinetic energy. There would appear to be considerable doubt as to the accuracy of such calculations particularly for the conduction figures. The inaccuracies are not great enough to be of importance in any combustion problems where other far grosser approximations are often necessary, but some interest would certainly attack to determining data for gases at high temperatures. The information might have an added interest in the case of conduction as throwing further light on the rates of energy interchange between vibrational and translational degrees of freedom during collisions, about which precise information is lacking, and which is of great theoretical interest.

Thermal conduction and diffusion refer to stream line conditions. The corresponding phenomena in turbulent heat transfer and turbulent mixing are very much more difficult to treat. In fact, as is well known, in all problems of turbulent flow no complete theoretical treatment is yet possible; measurements have to be made for each type of system about which information is required; then extrapolation of the results to cover the case of systems which do not differ greatly from the measured system, can be made by means of dimentional and similarity principles. Much further development of aerodynamic theory will be needed before this type of problem can be treated fundamentally. Experimentally, investigation will have to be confined to special cases as they arise.

(2). *Heat Transfer by Radiation.* So far as combustion problems are concerned interest attaches principally to radiation from flames. Engineering handbooks provide empirically determined data on the total radiation to be expected from hot gases, and special studies have also been made on the radiation from flames, such as that of Hartley (I.G.E. Trans. p. 466, 1932). The data thus available should enable approximate estimates to be made in practical problems.

The theoretical treatment of radiation, bound up as it is with the difficult subject of transition probabilities, is still far from providing the means of calculating practical data. And in this connection an even simpler question has as yet received no final answer. Both Gaydon, Hartley and other authors have pointed out that it is not yet known whether the vibrational energy in flames has a statistical distribution corresponding to the flame temperature, or whether the vibrational degrees of freedom still retain abnormal energy resulting from the chemical reactions.

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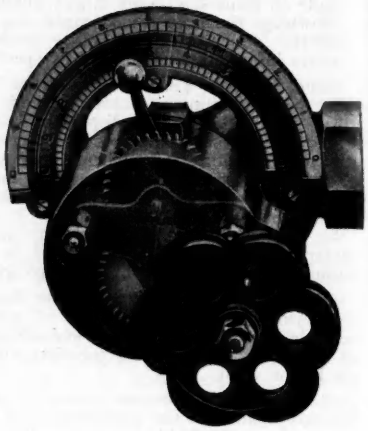

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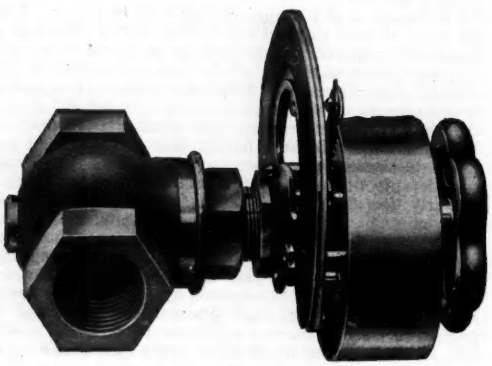

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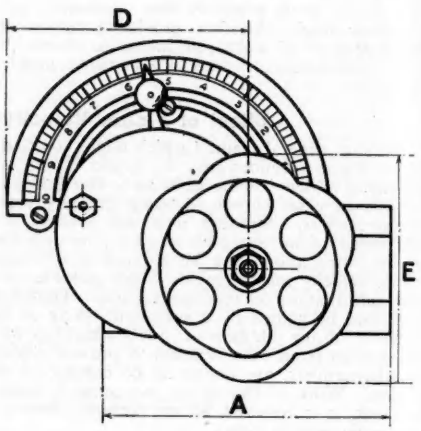

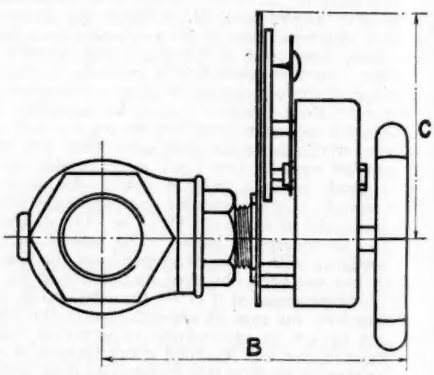

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3	6¼	9⅝	5¼	2⅞	5½
4	8	11⅛	5¼	2⅞	5½

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In other words, it is not known whether the vibrational radiation is thermal or chemi-luminescent. This, of course, is of some practical importance since the radiation data determined on hot gases would not be applicable to flames if part of the flame radiation *is* chemi-luminescent.

(3). *Heat Transfer from Hot Gases to Solids (other than by Radiation).* In a recent paper Kilham (I.G.E. Communication 307, No. 233) has discussed the question of heat transfer from flames to solids. He considers that the mechanism of heat transfer from flames may differ from the heat transfer from inert gases at the same temperature; that is to say, in addition to the purely physical heat transfer, energy may be communicated from flames to the solid surface by other methods. These other methods include deactivation on the surface of product molecules produced in the excited state, catalytic combustion reactions occurring on the surface and equilibrium shifts occurring in the reacting gases.

So far as the normal purely physical heat transfer from gas to solid is concerned, we are here again in that complex field which can only be dealt with by combination of direct measurement and extrapolation based on dimensional considerations. Kilham chose as his first line of investigation the case of a heat transfer from a gas stream to a cylinder whose axis is at right angles to the stream; he chose this precisely because more heat transfer data existed for this arrangement than for any other. He points out, however, that "In the case of a stream of gas flowing parallel to a surface it is not feasible to correlate the limited data available by the similarity method."

If this last conclusion is correct, it appears that a considerable field of investigation into rates of heat transfer from hot gases to solids under different geometrical conditions is awaiting to be undertaken.

Having reviewed the field of chemical and physical theory relevant to combustion problems, a survey must now be made of some of the principal branches of combustion investigation in which these theories are applied.

(1). *Propagation of Explosion.*—The rate of propagation of flames in explosive mixtures has been the subject of a great deal of experimental work. These velocities are determined in a great number of ways, including the photographic rate of propagation in tubes, explosions in soap bubbles, measurement of the rate of gas flow and the shape of flame in a gas burner, &c. These methods need not, however, be discussed here.

From the theoretical point of view the possibility of calculating the rate of propagation may be said to represent the ultimate aim of all combustion research; that is to say, when enough is known about all the different aspects of combustion to enable an accurate calculation of flame velocity to be made, there will not be much else left to know.

Lewis and von Elbe have already made an attempt to calculate a velocity in the case of a particularly simple chain reaction, *viz.*, the decomposition of ozone. They have to make a number of simplifying assumptions but the final result gives a value of the right order when compared with the experimental figures. The choice of a chain reaction rather than a thermal reaction would appear to complicate the calculation, and it is suggested that it might be worth while to attempt an analysis of the propagation of a flame in the case of a purely thermal reaction, if such a one could be found, and to compare the result with an experimental value.

For the calculation of flame velocity, a knowledge is needed of the following data:

(a). Kinetics of the reactions involved, *i.e.*, the effect of temperature and composition on rate.

(b). Thermal conductivity of the gases.

(c). Diffusion coefficients of the gases.

(d). Specific heats and heats of reaction.

Even, however, with all this data available, the difficulties of the calculation would be very great, but the importance of the subject would justify a great effort being made to find a solution.

(2) *Flame Structure.* The structure of flames is a very interesting and practically useful subject. A great deal of the theory has been developed by Mache (Die Verbrunnengserschheinnungen in Gasen, 1918). More recently, Lewis and von Elbe have published a paper in the Journal of Chem. Physics (1943 p. 75) in which they have made further very important contributions to this subject by the remarkably simple device of adding MgO powder to the flame and photographing the stream lines so rendered visible. This method has such obvious advantages for the study of flames that it will probably be included in the programme of the Gas Research Board for the purpose of investigating any flame problems to which it can conveniently be applied. One possibility is the study of the flow of air into a flame. In the flames studied by Lewis and von Elbe, conditions were specially chosen to give stream line flow, and the entry of the air to the outer cone would, if this is so, be due to pure diffusion. Examination of the diverging flow lines in Lewis and von Elbe's diagrams makes it difficult at first sight to believe this can be so, and further investigation of the method of entry of air into such flames is indicated. Study of turbulent flames is another obvious application of the method.

As a further development of the powder method, efforts could be made to reduce the size of the powder particles and to increase the degree of magnification with a view to studying the fine structure of the motion of the gases. Carrying this to its logical conclusion, it might even be possible to apply the ultra-microscope. Smoke particles which are fine enough to partake of Brownian movement can be observed in the ultra-microscope, and using particles of this order of fineness it should be possible to observe the fine structure of the motion of gases in the turbulent state. Similar experiments have been conducted by Fage and Townend for liquids. The interesting regions at the edge of the burner mouth, and at the interface between the gas and the air, might provide specially interesting information if examined in this way.

Some version of the powder method should be very useful in the design of all forms of gas burner where, for instance, it is desired to investigate flow conditions at the point of injection of primary air, and inside the burner tube. It is worth while emphasising that the powder method probably provides one of the simplest and most certain methods of determining the normal burning velocity.

Schlieren photography, which in the past has been extensively used for the study of flames, also provides a useful valuable method of investigation which will doubtless continue to find many applications in the future.

One of the important practical problems connected with flames is the maximum rate of heat generation per unit volume. In this connection certain experiments have been reported recently in which gas was burnt in a cylindrical chamber at a rate of 110,000,000 B.Th.U's per cu.ft. Apart from this figure only rather meagre information is available concerning this week, but what there is prompts the following speculations:

As far as can be made out, the gas is streaming through the burner at a rate which is perhaps 15 times the normal linear burning velocity for a theoretical air-gas mixture. This would appear to show that the primary combustion process is occurring far faster in the tunnel burner than in a normal flame, and it would be interesting to know how this can be. A higher rate of combustion might be due to a higher temperature in the combustion zone; but a higher temperature in the combustion zone could only be caused by a reduction in radiation loss to the surrounding walls. In view of the extraordinarily small volume of the primary combustion zone in an ordinary flame the loss of heat by radiation from this zone cannot in any case be very great, and hence no great difference of temperature in the combustion zone can be expected by simply reducing the radiation loss. An alternative explanation of the high combustion rate is that high turbulence increases the rate of heat transfer from the combustion zone to the cold gas, and hence decreases in a large proportion the volume of the preheating zone. A further possibility is that surface combustion is responsible for the higher rate. Investigation of this problem would certainly provide an interesting field for research.

Apart from the applications mentioned above, a great deal of combustion research has been devoted to the problems arising in the internal combustion engine. This includes the interesting fields of the propagation of detonation waves, the causes and prevention of knock and, generally speaking, the whole field of combustion reactions occurring under high pressures. Discussion of these problems, however, is not considered appropriate to this contribution which has necessarily aimed at discussing aspects of the whole subject of combustion which are most nearly related to the practical problems facing the Gas Industry.

Stream of Hot Gases

Dr. **R. S. Silver** (Joint Assistant Director, Gas Research Board): For the present purpose I shall make this contribution very brief and therefore it will be somewhat sketchy. I hope, however, that it will outline some ways in which I think it will be useful to consider certain problems in the utilization of gas in appliances.

The word "flame" is, in a sense, an accident. If the reactions of gases combustible with oxygen in the air had had no energy levels in the visible spectrum, human language would probably not have contained the word "flame." We should have detected what was going on only by senses other than sight, and should probably have spoken of "a stream of hot gases" (run together in a nice mouthful by the Germans!). I think it is very useful to recall this and to consider that a preponderant part of the utility of flames comes from the various properties describable as a stream of hot gases. More important, the same description implies some of the limitations governing their utility.

Having said this, we might reasonably expect that the literature on flames would be full of aerodynamic studies, of theories and of experiments on the flow of the stream. Instead of this, we draw a blank. It is obvious enough that practical improvements of appliance manufacturers have taken account of aerodynamic factors in design, but the literature makes it clear that the development has been empirical. Now, theories of flame have been

worked out in some detail involving, no doubt, important sub-phenomena like thermal conductivity, and the nature of the molecular reactions, whether chain or otherwise, and in most cases these ignore altogether the aspect of a flame as a stream of hot gas. Surely there is something wrong in that situation? The usual justification for ignoring one aspect of a problem is when its effect is small as compared with others. That is certainly not true of the aerodynamic effects in flames—a gust of wind will extinguish a flame quite as certainly as the introduction of chain-breaking molecules!

The fact is that the readily visible phenomena in flames have attracted, and perhaps distracted, our attention. They revealed a definite structure—and theory of flames has tended to start from the attempts to explain that structure. But we have to ask, to what extent is that structure really relevant to uilization problems? So long as we get a stream of gas flowing in a steady state at a desired temperature in a desired volume and with an appropriate overall shape, the internal structure is of no practical importance. It can be of importance only if it is the thing which governs the stability of the overall stream. Which comes first: the stability of the overall flow or the stability of the internal structure?

The answer is obvious. Since you cannot set up an internal structure in a thing which is not in itself stable, the primary requirement for a stable flame is a stream of gas with sufficient kinetic energy in the axial direction to overcome resistance to motion in that direction if at constant pressure, or perhaps with a sufficient pressure gradient to overcome the resistance. Given that, the rates of reaction and of transfer or propagation of the radicles concerned will set up *some* internal structure.

Stability of Flow

The problem is referred back to the possible sources of kinetic energy for the axial motion of the stream. It must be clearly realised that there are only two possible origins: (1) The initial kinetic energy of the gases as supplied from the jet or jets, and (2) such proportion of the work done by gaseous expansion in the hot region as may be effective in the axial direction. If the sum of these is inadequate, the stream cannot be maintained and the flame must go out in some way.

The first of these two terms is easy to calculate. For an ordinary burner in which only the combustible gas is supplied under pressure, the axial energy for air molecules comes from collision. The resultant energy after entrainment can be calculated on the basis of conservation of momentum. For a burner in which both air and gas are supplied in axially directed jets, or in a premixed jet, the kinetic energy for the air is provided by the pressure drop. Hence, for the same thermal output, *i.e.*, same gas flow, the kinetic energy of unit weight of mixture is much less in an ordinary burner than in a burner with air supplied under pressure. The hot gas stream must have very different stability characteristics in these two cases.

The second origin of axial kinetic energy—gaseous expansion—is much more difficult to consider. The natural tendency of the expansion is multilateral and the only way in which it can contribute to directed velocity is where there is a path of least resistance. Now, it may be that what I called the sub-phenomena of flames, and more especially the internal geometrical structure which the sub-phenomena determine—it may be that these canalize the heat release in some way and so provide paths of least resistance. If so, then at this point we have a way in which internal structure may contribute to overall stability. There may be an interplay, so that in the final stable flame the internal structure and overall stability are co-determined in a complex equilibrium. That is almost certainly the true situation in an ultimate analysis. But before considering that complex, it has to be remembered that there are other factors determining paths of least resistance whose effects may be much greater than those of the internal sub-phenomena.

Path of Least Resistance

The most important of the factors which can determine paths of least resistance is, perhaps, the gravitational field, which canalizes expansion effects into convective circulation. The overall stability of a flame may be very much a convection problem, and may be very different for upward, horizontal and downward flames. Indeed, it must be so except when the supply pressure gives a kinetic energy large compared with the magnitude of possible convection effects. The general theory of expansion convection has not been well developed. The only field in which much has been done is the study of circulation in boilers. In that case, the boundaries of flow are confined. There is considerable scope for theoretical work on unconfined convection, as very little has been done, and we have made some beginning recently in the Gas Research Board. The relevance of this work is chiefly to flame stability, but it may prove useful in connection with convective appliance design.

Another important factor is that the forward momentum of the stream can also provide resistance to backward movement, and so tends to canalize expansion in the direction of motion. Of equal importance is that the expansion itself causes a part of the resistance, since unless the cross-sectional area alters to suit, the stream has to be accelerated.

In general, then, the relation between the gaseous expansion and the kinetic energy available for flame stability requires theoretical study, and this must commence with the appropriate form of the Bernoulli equation. I would like to conclude with a brief account of the difficulty and interest which that presents.

Effect of Heat Supply on the Flow Equation

It is well known that the ordinary treatment of the Bernoulli equation, which is for adiabatic conditions, gives the result that a critical rate of flow per unit area is reached with a certain pressure drop. That critical drop is known to correspond to the ordinary (adiabatic) velocity of sound. But when the equation is modified to allow for a rate of heat supply to the fluid, the solution becomes exceedingly difficult. It may appear an elementary problem, but the fact is that, so far as I am aware, the only case which has yet been solved is when the rate of heat supply is just sufficient to maintain the original temperature. (Of course, in adiabatic flow, the temperature drops with the pressure.) This particular rate of heat supply corresponds to isothermal flow. The solution shows again a critical rate of flow per unit area—but at a lower value than in the entirely unheated case. This lower value corresponds to an isothermal velocity of sound. If we have a gas stream which experiences a very high rate of heating then, following the above pattern, we can expect that there will also be some critical rate of flow per unit area at a still lower value, and perhaps substantially lower. I want to emphasize here that this problem refers to, and is resolved, even in the case of an inert gas with some extraneous heat supply. It must be present in a more complex form in the case of a burning gas. Here, the general solution of the Bernoulli equation for gases experiencing a high rate of heating would be of great value in all flame studies, and particularly in the case of industrial burners, the concentrated combustion burner and, of course, where flow is most important, viz., in the combustion turbine. Even in respect of noise alone we could expect it to be valuable since critical rates of flow are bound up with the generation of shock waves.

Accordingly, we are intending in the work of the Gas Research Board to study this flow problem, to try to develop the theory of it and to examine it experimentally probably with the Schlieren and magnesium powder methods referred to by Dr. Strickland-Constable. It will probably also be of use, especially for industrial burners, to study noise by using sound analyzer apparatus.

I have noticed that in the remarks of previous speakers that the rates of combustion are referred to in terms of B.Th.U.'s generated per hour per cu.ft. I wonder whether in connecting that up with the study of these problems there would be any advantage in interpreting the value as B.Th.U. per cu.ft. per hour of total mixture used. That could be expressed as so many B.Th.U. per cu.ft. per hour, corresponding roughly to a volume velocity of four times per second in the case of a 500 B.Th.U. gas. That higher value might be worth interpreting in that way. I do not know whether there is any objection to that.

Oil Gas

Dr. **H. Hollings**: I wish to comment very briefly on Dr. Townend's suggestion that the Gas Industry has such a very restricted interest in the chain reactions and other phenomena of the slow combustion of hydrocarbon molecules. I venture to suggest that Dr. Townend has overlooked the possible rôle of these reactions in processes of gas manufacture. I refer first to the Dayton process of making oil gas, still used, I believe, in Canada. My knowledge is limited to publications in the literature, but I suggest that a scientific analysis of that process might show that it depended upon just such reactions as Dr. Townend and Prof. Newitt have been discussing.

In the Gas Light and Coke Company we were fortunate a few years ago in having one of Dr. Townend's own pupils; various methods of converting gas oil to a permanent gas have been studied. We have had the usual disappointments, but it now appears that we are within sight of the establishment of a thermally self-supporting process wherein gas oil from a pressure jet is burnt in an atmosphere greatly deficient in oxygen. The reaction temperature may reach 750° C., but we believe that in front of this high temperature zone we have the true slow combustion phenomena. It is at least significant that the products frequently smell very strongly of aldehydes and that the tar oil produced has pronounced acidic properties.

Because this is a continuous and a thermally self-supporting process, the plant which we envisage is very simple in character and will cost much less than conventional gas plant. It may prove to be a permanent feature of our system for meeting peak load demands for gas.

There is still much research work to be completed before it would be appropriate for Dr. MacCormack to publish a detailed account. I might mention that many gas engineers and chemists have already seen a modification of our apparatus which was adapted for use in horizontal retorts during the recent coal shortage. This modified process was not thermally self-supporting since the retorts were heated by coke. We will publish a full statement of the scientific work and design of the permanent plant as soon as possible.

GAS STOCKS AND SHARES

Stock markets re-opened quietly after the Whitsun holiday with a small turnover and few price changes of note. Conditions were irregular throughout the week, and the grave warnings of Mr. Herbert Morrison and the Chancellor of the Exchequer at the Labour Party conference at Margate with regard to Britain's economic position resulted in a substantial fall in British funds. There was little activity in the industrial market, but prices tended to harden towards the end of the week.

In the gas stock market there were few price changes. Increased interest in Imperial Continental was aroused by the issue with the annual report of a statement showing the progress that has been made during the past year in the post-war reconstruction and expansion of the Association's gas undertakings in Belgium. Rises and falls during the week were as follows:

OFFICIAL LIST

Croydon 4 p.c. irred pref. ...	99 —104	+ 1
Gas Light & Coke ord.	22/3— 23 3	— 3d.
Do. 3½ p.c. max. ...	80 — 85	+ 2
Newcastle & Gateshead ord. ...	24/— — 26/—	+ 6d.
Watford & St. Albans 5 p.c. pref.	105 —110	+ 2

Quotations on the London Stock Exhange

When ex-Dividend	Dividends Interest.% Last Yr.	Prev. Yr.	NAME.	Quotations May 29
Mar. 12	4	3½	Alliance & Dublin Cons. Ord.	21/6—23/6
April 30	5	5	Asscd. Gas & Water U'd'tgs Ord.	19/—21/—
"	6	6	Do. Deferred	19/—21/—
Mar. 12	4½	4½	Do. 4½ p.c. Red. Cum. Pref.... ...	20/—22/—
"	4	4	Do. 4 p.c. Red. Cum. Pref.	19/6—21/6
"	4	4	Do. 4 p.c. Irred. Cum. Pref.... ...	19/—21/—
Feb. 26	7	7	Barnet Ord. 7 p.c. max.	158—163
Mar. 12	5	5	Bath Cons. Ord .5 p.c. basic	107—112
Nov. 18	...	10	Bombay, Ltd., Stock	50/—52/—
Jan. 29	8½	8½	Bournemouth Std. 5 p.c. sliding scale ...	173—178
"	7	7	Do. 7 p.c. max. div.	159—164
"	4	4	Do. 4 p.c. Pref.	101—106
"	6	6	Do. 6 p.c. Pref.	128—133
Feb. 12	...	3½	Do. 3½ p.c. Red. Deb.	95—100
Dec. 11	...	4	Do. Perp. 4 p.c. Deb.	103—108
Feb. 26	5·35	5·55	Brighton, &c., 5 p.c. Std. Cons.	105—110
"	6·3	5⅞	Do. 6 p.c. Std. Cons.	115—120
Dec. 11	...	5	Do. 5 p.c. Perp. Deb.	120—125
Feb. 26	5	5	Bristol, Gen. Cap. 5 p.c. max.	110—113
Dec. 11	4	4	Do. 4 p.c. New Deb. Red.	100—105
Mar. 12	7½	7½	Brit. Gas Light Ord.	115—120
Dec. 31	5½	5½	Do. 5½ p.c. 'B' Cum. Pref.	110—115
Dec. 11	...	4	Do. 4 p.c. Red. Deb.	97—102
Feb. 12	10	10	Cambridge U. & T. Orig. 10 p.c. Cons. ...	190—200
"	5	5	Do. 5 p.c. Cons. 'C'	100—105
"	7	7	Do. 7 p.c. Cons. 'B.'	135—140
April 30	...	4½	Cape Town, Ltd., 4½ p.c. Cu. Pf.	17/—19/—
Feb. 12	6½	6	Cardiff Con. Ord.	122—127
Mar. 12	5	5	Cheltenham, 5 p.c. basic Cons. Ord. ...	103—108
Dec. 11	...	4	Do. 4 p.c. Perp. Deb.	98—103
Feb. 12	5⅞	5⅞	Chester United Ord.	120—125
Nov. 18	...	9½	Colombo Ltd., Ord.	40/—42/6
"	...	7	Do. 7 p.c. Pref.	23/6—25/6
Mar. 26	...	5	Colonial Gas Assn. Ltd. Ord.	15/—20/—
"	8	8	Do. 8 p.c. Pref....	22/6—24/6
Feb. 12	5	2	Commercial Ord.	84— 87
Dec. 11	3	3	Do. 3 p.c. Deb. Perp.	90— 95
Feb. 12	...	5	Do. 5 p.c. Irred. Deb....	118—123
"	6	6	Croydon sliding scale	118—123
"	5	5	Do. max. div.	101—106
"	...	4	Do. 4 p.c. Irred. Pref.	99—104
Dec. 31	...	4	Do. 4 p.c. Perp. Deb....	100—105
"	...	5	Do. 5 p.c. Perp. Deb....	120—125
Feb. 12	8½	7½	Derby Cons. Ord.	140—150
Dec. 11	...	4	Do. 4 p.c. Red. Deb.	100—105
Feb. 12	5	5	East Hull Ord.	97—102
"	5	5	East Surrey 'B,' 5 p.c.	100—105
"	6	6	Do. 6 p.c. Cum. Pref....	120—125
Dec. 31	...	5	Do. 5 p.c. Irred. Deb.	118—123
Feb. 26	6⅜	6⅜	East Wight Cons. Ord.	110—120
Mar. 12	5	5	Eastbourne 'A'	97—102
"	3½	3½	Do. 'B'	90—100
Nov. 18	...	5	Gas Consolidation Ord. 'A'	20/—22/—
"	...	5	Do. Ord. 'B'	20/—22/—
May 14	...	4	Do. 4 p.c. Red. Cum. Pref.	19/6—21/6xd
Feb. 12	5	5	Gas Light & Coke Ord.	22/3—23/3
"	3½	3½	Do. 3½ p.c. max.	80— 85
"	4	4	Do. 4 p.c. Con. Pref.	101—104
Dec. 31	...	3½	Do. 3½ p.c. Red. Pref....	99—102
Dec. 2	...	3	Do. 3 p.c. Con. Deb.	95— 98
"	...	5	Do. 5 p.c. Deb.	103—106
"	...	4½	Do. 4½ p.c. Red. Deb.	104—107
Mar. 26	...	3½	Do. 3½ p.c. Red. Deb....	99—102
Mar. 12	5	5	Gloucester Cons. Ord.	103—108
Feb. 12	2	Nil	Great Yarmouth (8½ p.c. max)	13½— 15½
Feb. 26	7½	8¾	Guildford Cons. Ord.	135—140
Feb. 26	5	5	Hampton C't, 5 p.c. Cons. Ord.	103—108
"	5	4½	Hartlepool G. & W. 5 p.c. Ord.	100—105
Oct. 21	...	5	Hastings & St. L. (5 p.c. Std.)	88— 93
"	...	3½	Do. (3½ p.c. Std.)	78— 83
June 17 '46	6	6	Holyhead & N. Wales Ord.	22/—24/—
April 16	5	3⅜	Hornsey 3½ p.c. 'B'	95—100
"	7½	5⅜	Do. 5 p.c. Std.	120—125
May 14	8½	8	Imperial Continental Cap.	124—129xd
Jan. 29	3½	3½	Do. 3½ p.c. Red. Deb....	98—102
April 16	7½	7½	Lea Bridge Co., Cons. Ord....	146—151
Feb. 12	5½	5½	Liverpool 5 p.c. Ord.	114—119
Mar. 12	7½	8½	Luton Cons. Ord. 'A'	130—140
"	6½	6⅜	Do. Ord. 'B'	115—120
Jan. 15	...	7	Malta & Med'n., 7 p.c. 1st Pref.	100—110
"	...	7½	Do. 7½ p.c. 2nd. Pref....	105—115
Feb. 12	5·225	5·225	M.S. Utility 'A' Cons.	98—103
"	3·722	3·722	Do. 'B' Cons.	70— 75
"	5	5	Do. 'C' Cons.	98—103
"	...	4	Do. 4 p.c. Cons. Pref.	98—103
April 30	4	4	Montevideo, Ltd. Ord.	127—132
Feb. 12	5⅛	5⅛	Newcastle and Gateshead Ord.	24/—26/—
Dec. 31	...	3½	Do. 3½ p.c. Perp. Deb.	97—100
Mar. 12	7	6	Newport (Mon.) Cons.	112—117
Dec. 11	...	5	Do. 5 p.c. Perp. Deb....	120—125
April 30	6⅝	6⅝	North Middlesex 6 p.c.	128—133
"	5	5	Do. 5 p.c. Pref.	103—108
Feb. 12	...	5	Northampton Cons.	104—109
Jan. 29	10	10	Oxford, Cons. Ord.	170—180
Dec. 11	...	5⅛	Plymouth & Stone Ord.	105—110
"	...	8½	Do. Addl.	14½— 16½
"	...	7½	Do. New	14— 16
Mar. 12	...	5	Do. 5 p.c. Deb. Perp....	117—122
Feb. 12	7½	7½	Portsmouth & Gosport Cons.	140—145
"	5	5	Do. 5 p.c. max.	100—105
"	10	10	Preston 'A'	170—190
"	7	7	Do. 'B'	132—137
June 24	46	2	Primitiva Holdings, Ltd. Ord.	11/—13/—
Dec. 31	6	6	Do. 6½ p.c. Red. Cum. Pref.	100—105
Feb. 12	5	5	Reading, 5 p.c. max.	100—105
Dec. 11	...	4	Do. 4 p.c. Perp. Deb....	98—103
Feb. 12	5	5½	Romford, Ord.	105—110
Mar. 26	...	4	Do. 4 p.c. Debs. Red....	97—102
Sept. 9	...	5½	Severn Val. Ltd. Ord.	20/—22/—
Feb. 26	...	4½	Do. 4½ p.c. Cum. Pref.	20/—22/—
"	6½	6½	Sheffield Cons....	138—143
Dec. 31	...	4	Do. 4 p.c. Red. Deb.	100—105
Feb. 12	...	5	South East'n Gas Ltd. Ord.	20/3—21/3
Feb. 26	4½	4½	Do. 4½ p.c. Red. Cum. Pref.	19/6—21/6
"	4	4	Do. 4 p.c. Irred. Cum. Pref.	19/—21/
Feb. 12	5	4	South Metropolitan Ord.	95 — 98
"	...	6	Do. 6 p.c. Irred. Pref....	122—127
"	...	4	Do. 4 p.c. Irred. Pref.	98 —103
"	...	3	Do. 3 p.c. Perp. Deb.	93 — 98
"	...	5	Do. 5 p.c. Red. Deb.	98 —103
Jan. 15	...	5	South Suburban Ord. 5 p.c.	110 —115
Jan. 29	5	5	Do. 5 p.c. Perp. Pref....	105 —110
"	...	5	Do. 4 p.c. Perp. Pref....	98 —103
"	...	4	Do. 3½ p.c. Red. Pref....	98 —103
"	...	3½	Do. 5 p.c. Perp. Deb....	120 —125
Dec. 11	...	5	South West. G. & W. Ltd. Ord.	19/—21/—
April 30	...	5½	Southampton Ord.	104 —109
Feb. 12	5	5	Sunderland Ord.	123 —128
Jan. 29	6	6	Swansea Ord.	83 — 88
Feb. 12	4½	3½	Do. 5½ p.c. Red. Pref.	100 —105
"	...	5½	Swindon Cons. Ord.	113 —118
Mar. 12	7	6⅛	Tottenham Ord.	110 —115
"	5	5	Do. 5 p.c. Pref.	105 —110
"	5	5	Do. 5½ p.c. Irred. Pref.	113 —118
"	5½	5½	Do. 4 p.c. Perp. Deb....	100 —105
Dec. 11	...	4	Tunbridge Wells, 4 p.c. Sliding	125 —135
Sept. 23	...	7½	U. Kingdom Ltd. Ord.	22/—24/—
Nov. 11	...	6	Do. 4½ p.c. 1st Cum. Pref.	19/—21/xd
May 14	4½	4½	Do. 4 p.c. 1st Red.Cum.Pref.... ...	19/6—21/6xd
"	4	4	Do. 4½ p.c. 2nd Non.Cum.Pf.... ...	19/6—21/6
Dec. 11	...	4½	Do. 3½ p.c. Red. Deb....	100 —105
Mar. 12	...	3½	Uxbridge, &c., 5 p.c.Cap.	127 —132xd
May 14	6⅛	6⅛	Do. 5 p.c. Pref.	104 —109xd
"	5	5	Do. 5 p.c. Perp. Deb.	119 —124
Dec. 2	...	5	Wandsworth Cons.	110 —115
Feb. 12	5	5	Do. 4 p.c. Pref....	98 —103
"	...	4	Do. 5 p.c. Irred. Deb....	120 —125
Dec. 11	...	5	Do. 4 p.c. Irred. Deb....	100 —105
"	...	4	Watford & St. Albans Ord.	110 —115
Feb. 12	5	5	Do. 5 p.c. Pref.	105 —110
"	...	5	Do. 5½ p.c. Pref.	115 —120
"	5	5	Weymouth Ord. (5 p.c. Basic)	97 —102
"	11	11	Woking District "A" Ord....	190 —200
"	7·7	7·7	Do. "B" Ord.	133 —138
"	8	8	Wolverhampton Cons. Ord.	123 —128
Mar. 26	5	5	York Cons. Ord.	105 —110